COMMERCIAL TRUCK SIMULATORS RE-ASSESSMENT AND EVALUATION FINAL REPORT

December 2002

Foreword

The purpose of the Commercial Truck Simulators Re-Assessment and Evaluation Program is to assess the functional capabilities of various simulators in support of the planned Commercial Truck Simulator Validation (SimVal) study to be conducted by the Federal Motor Carrier Safety Administration (FMCSA).

The contractor hired for the Commercial Truck Simulators Re-Assessment and Evaluation Program assembled a multi-disciplinary team to objectively and effectively evaluate the simulators. Included in the team were experts in commercial driver training, simulator use and development of experimental programs on simulators, an award winning truck driver, and human factors experts.

The information derived from the Truck Simulators Re-Assessment Project provides FMCSA with an understanding of the characteristics and functionalities of the truck simulators assessed, availability of basic driving scenarios replicated on the simulator, as well as the availability of advanced simulator capabilities, such as emergency maneuvers, that cannot be performed safely in actual driving situations. This information contained in this report will also be useful to other researchers and truck simulator end users.

Members of the general public will find this report interesting and informative, as will anyone interested in the study of truck simulators. This report is considered final, in that it fully documents the results of the aforementioned study, and that the information provided herein is not superceded by other research.

Notice

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John Pierowicz, Jerry Robin, MBA, Valerie Gawron PhD, MBA, Ginger Watson PhD, Bill Nestor, Wade Murphree	

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This program was administered through the Federal Motor Carrier Safety Administration (FMCSA). The FMCSA Program Manager is Mr. Jerry Robin.

16. Abstract

The Federal Motor Carrier Safety Administration (FMCSA) will conduct a study to determine if empirical evidence can support the use of a low - to mid-cost truck simulator to enhance commercial motor vehicle (CMV) driver training, testing, and implications for licensing. Based on preliminary findings, FMCSA believes that simulators hold considerable promise for improving commercial driver performance and highway safety if their value can be sufficiently demonstrated. In the first phase of the Commercial Truck Simulator Validation (SimVal) Study, FMCSA published an initial truck simulator assessment report (1996), which indicated that simulation was sufficiently mature for validation purposes. A research design (1999) was then developed to validate the use of simulation technology.

This report describes a second, more detailed, truck simulator re-assessment to learn about technological progress of available truck simulators since the publication of the initial report. The re-assessment is based on the simulator functionalities described in the research design report. The completion of this report will ensure that FMCSA has more up-to-date information on commercially available truck simulators in the United States.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m2	cd/m2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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EXECUTIVE SUMMARY

Simulators have been successfully used for training within the military and commercial sectors for several decades. Now, relatively low-cost, full-mission, high-fidelity Commercial Motor Vehicle (CMV) simulators are available in the marketplace and are being used by various organizations within the trucking industry. As the cost of these simulators continue to decrease and their capabilities appear to increase, their use will likely increase as well. Therefore, truck simulators may be useful tools to supplement training, testing, and licensing of CMV operators if their benefits can be demonstrated.

The purpose of the Commercial Truck Simulators Re-Assessment and Evaluation Program is to assess the functional capabilities of various simulators in support of the planned Commercial Truck Simulator Validation (SimVal) study by the Federal Motor Carrier Safety Administration (FMCSA). However, before the results are discussed, it is important to understand the background of the SimVal Program. Much of the discussion of the SimVal study contained in this section is adapted from previously published government documents and professional reports, as specified in the reference section of this report.

One of the primary objectives of the SimVal study is to examine how simulator-based training, as compared to conventional training methods, can enhance the training effectiveness and improve the tractor-trailer driver performance. The study also identifies opportunities for using truck driver training simulator technology and examines the cost implications.

The planned SimVal study will build on a number of interrelated research activities conducted by FMCSA over the past several years. The initial truck simulator assessment determined that truck simulator technology was sufficiently mature to conduct a validation study. Based upon this promising information, FMCSA then developed and published a detailed SimVal Research Design Report describing the methodology to conduct the empirical SimVal study. Then FMCSA conducted a second, more detailed truck simulator assessment, which is the subject of this report.

The Research Design reflects the input of industry based on two peer reviews: one on the driving scenarios to be used in the study and a second on the methodologies of the Research Design itself. The Research Design consists of three parts, each of which also includes a pilot test. The three parts are as follows:

Part 1 – Transfer of training
Part 2 – Advanced simulator capabilities
Part 3 – Longitudinal study

Part 1 of the study addresses the forward transfer of training (conventional tractor-trailer training vs. simulator-based training) for entry-level drivers. Part 2 provides for an evaluation of the advanced capabilities of the simulator to replicate the more complex driving skills, such as the operation of double and triple combination vehicles, evasive maneuvers, jackknives, and driving on black ice. Part 3 is a continuation of Part 1 and will determine if simulator-based training ultimately results in reliable enhancement of driver's performance over time. Thus, the

student driver's post training driving record will be examined at 3 and 12 months following the completion of the Commercial Drivers License (CDL) examination and full-time employment as a tractor-trailer driver.

The Truck Simulators Re-Assessment Report documents the performance of a number of commercially-available truck simulators for the planned FMCSA SimVal study as previously described. This program assessed advances in previously evaluated systems and assesses new systems available in the United States. Contractor personnel performed web searches, reviewed promotional literature, and used professional contacts to assemble a list of system potentially capable of satisfying the criteria of the SimVal Research Design Report. This process produced a master list of 23 simulators that fit the general system criteria. The final list of candidate simulators for evaluation was derived from the master list by deleting those systems in which:

- The company was no longer in business
- The simulator was not commercially available in United States
- An operational system was not available for evaluation
- A truck configuration was not available
- The manufacturer recommended another specific model

The final list of simulators meeting the criteria for evaluation included systems from Doron Precision Systems, I*SIM Corporation (now GE Capital I*SIM), Digitran Simulation Systems, Lockheed Martin Information Systems, FAAC Incorporated, and Thales Training and Simulation Systems.

To evaluate the truck simulators, an Expert Team was assembled. The individuals who comprised this Team brought skills in specific areas necessary to objectively and effectively evaluate the simulators. Included in the team were experts in commercial driver training, simulator use and development of experimental programs on simulators, an award winning truck driver, and human factors experts.

Each simulator was evaluated using a simulator assessment tool. The assessment tool was based on the SimVal Research Design Report. The assessment tool identified key elements within the Research Design necessary to conduct the SimVal study, such as availability of various roadway configurations, backing maneuvers, shifting techniques and advanced capabilities. The resulting assessment tool provided a standardized format to assess simulator capabilities and driving scenarios addressed in the Research Design. Over 183 distinct factors were contained in the assessment tool. Each simulator factor was assessed in terms of "Adequate," "Not Adequate," or "Not Available." These assessment categories were consistent with the initial simulator assessment report. In addition, the assessment tool provided an area for the Expert Team's comments. These comments are included in this report to provide additional information relevant to the assessment of each factor.

As previously mentioned, the Expert Team evaluated six truck simulators. During each visit the team evaluated the functional capabilities of the simulator with respect to the factors listed in the simulator assessment tool. Each visit was conducted at the manufacturer's facility or at a customer site recommended by the manufacturer. The system assessments were developed

though a consensus process that included all members of the Expert Team. A synopsis of each of the simulator evaluations is provided on the following pages.

Doron Precision Systems L-300 VMT

The Doron L-300 VMT simulator is designed to provide close-quarter maneuvers training using a mock-up of a loading dock environment. This system is a "model/diorama" configuration employing three primary components:

1. Remotely operated scale model of a tractor-trailer equipped with a video camera
2. Staged mock-up of a loading dock, and
3. Mock-up of a tractor cab which includes gauges, steering, throttle, and brake which control the scale model; the trainee interacts with the projected images from the camera mounted within the scale tractor-trailer

The simulator is designed specifically for close quarter, low speed maneuvers. It provides appropriate visual cues for these types of maneuvers. The simulator was deemed adequate for the close-quarter, low speed maneuvers for which the system is designed. The system does not provide a motion base, thus motion cues are limited to the visual scene.

*I*SIM TruckSim*

The I*SIM TruckSim is a full mission simulator that uses a real tractor cab, with operational gauges and good replication of steering, braking, and throttle control. The cab is mounted on an actuator system that provides motion cues to the driver. The simulator is very good in duplicating the over-the-road visual and dynamic characteristics of a tractor-trailer. Double and tanker-trailer configurations are also available in this simulator. The simulator displayed good vehicle dynamic characteristics, for example the ability to realistically modulate vehicle braking effort. The simulator was very versatile in the set-up and performance of specific training scenarios. The simulator also replicates emergency and avoidance maneuvers. However, this simulator lacks some features that would be useful for driver training. For example, the system does not automatically tabulate driver performance results from the training session. Further, the system requires post-processing of data from the session to assess driver performance.

Digitran SafeDrive 1000

The Digitran SafeDrive 1000 simulator uses a "half-cab" system, duplicating the driver's seat and dashboard that provides basic controls of a tractor. This simulator does not utilize a motion base; however a seat shaker is used to convey limited motion cues. A wide variety of roadway configurations are available. The visual system of this simulator was generally adequate, but some visual details such as traffic signs and visibility down the roadway were not well replicated. However, the vertical and horizontal edges of projection screens were clearly visible to the driver, impacting the field of view. The scenario database provides insufficient traffic, with a lack of programmability of the available traffic. Several emergency and avoidance maneuvers scenarios are provided on this system. The SafeDrive 1000 replicates various tractor-

trailer configurations, such as double, triples, and tanker-trailer with various load levels.

Lockheed Martin Millennium Driver Trainer

The Lockheed Martin Millennium Driver Trainer uses a complete tractor cab mounted on a hexapod motion base. The cab provides a complete set of gauges and controls for the driver. Dynamic motion of the simulator in most situations was good; however, there was a noted exaggerated pitching motion during braking and acceleration. The tractor cab mirror system on the simulator replicates convex mirrors such as those used in the real world. The scenario database is extensive, with a good selection of roadway types in rural and urban locations. Although a large number of vehicles are available in the scenarios, the placement of vehicles in proximity to the simulated tractor-trailer was deemed inadequate for high-density traffic situations. The visual scene projected by the simulator was good, with adequate replication of buildings, roadways and roadside objects. The simulator provides a number of routine, emergency, and evasive driving scenarios. A good selection of automated tools for driver scoring and performance monitoring is available on this simulator.

FAAC Incorporated Driver Training System

The FAAC Driver Training System simulator uses a partial cab design with a seat shaker for road feedback to the driver. A full complement of gauges is provided that respond properly to the various inputs. In addition, the weighting of the feedback from the steering wheel is very good and the brakes can be modulated as in a real vehicle. The system assessed provided a single trailer configuration only. This simulator provides excellent graphics with good replication of the roadway, buildings, and roadside objects. In addition, the simulator provides sufficient vehicle traffic, with programmable behavioral characteristics, to enable the drivers to react to various traffic situations. The simulator provides a limited number of emergency and avoidance maneuver scenarios. The simulator has an excellent set of driver scoring and training tools which could also be useful for driver training and evaluation purposes.

Thales Training and Simulation Truck Simulator for Training (Trust) 800

The Thales Trust 800 simulator uses a cab-over tractor mounted on a hexapod motion base. The cab provides a full complement of controls and gauges for the driver. As is typical of cab-over models, the simulator employs a short-throw transmission. This transmission required excessive effort to operate. The Trust 800 can replicate tractor-trailer and tanker-trailer configurations. The mirrors are real mirrors that observe a scene generated by an LCD monitor at the back of the cab. This system is effective for rear views of roadway and scenery while performing backing maneuvers. Throttle response of the simulator was deemed inadequate, with a noted lag between input and response. In addition, brakes did not respond well to modulation. Simulator motion cues, such as pitch, roll, and vibration were good at low speeds, but less accurate at speeds above 35 MPH. The simulator provides a limited number of emergency and avoidance maneuver scenarios. The system has a good variety of roadway scenarios and also includes a simulated driving range which is useful for training of basic vehicle control maneuvers. The simulator's mountain scenarios were very good, providing a good variety of curves and uphill/downhill sections. Although the system can provide a large number of

vehicles in the scenarios, the actions of only one vehicle is programmable. The simulator has an extensive set of features for providing driver performance evaluation and feedback.

The information derived from the Truck Simulators Re-assessment Project will provide FMCSA with an understanding of the:

- Characteristics and functionalities of the truck simulators assessed. This is important because only one simulator will likely be employed in the follow-on SimVal Study.
- Availability of basic driving scenarios replicated on the simulator, e.g., backing and shifting.
- Availability of advanced simulator capabilities that cannot be performed safely in the real-world such as emergency maneuvers.

In addition, this information will be useful to other researchers and truck simulator end users.

It is important to note, the re-assessment initiative is not a side-by-side comparison of each of the reviewed simulators; rather, it was an evaluation of the capability of these simulators to support the criteria of the FMCSA SimVal Research Design.

1.0 BACKGROUND AND INTRODUCTION

The Federal Motor Carrier Safety Administration (FMCSA) recognizes that low-cost, full-mission, high-fidelity Commercial Motor Vehicle (CMV) simulators could be useful tools to supplement training, testing, and licensing of CMV operators. However, there is a lack of empirical data in both the private and public sectors relating to the transferability of simulator training to real driving, and to assess its usefulness, effectiveness, or efficiency.

FMCSA is planning to commence a Commercial Truck Simulator Validation (SimVal) study to examine how simulator-based training, as compared to conventional training methods, could enhance training effectiveness and improve the tractor-trailer driver performance. The study will identify opportunities to employ truck driver training simulator technology and examine the cost implications. The SimVal study will be the culmination of a number of interrelated research activities conducted by FMCSA over the past several years. The initial truck simulator assessment determined that truck simulator technology was sufficiently mature to conduct a validation study. The results of this initial evaluation were published in 1996. FMCSA then developed and published in 1999 a detailed Research Design to conduct the empirical SimVal study.

The Research Design study reflects the input of industry based on two peer reviews: one on the driving scenarios to be used in the study and a second on the methodologies of the research design itself. The detailed description of the Research Design Study contained below draws heavily from a FMCSA TechBrief publication originally published in 2000. The Research Design consists of three parts, each of which also includes a pilot test. The three parts were:

Part 1 – Transfer of training
Part 2 – Advanced simulator capabilities
Part 3 – Longitudinal study

Part 1 of the study addresses the forward transfer of training (conventional tractor-trailer vs. simulator-based training) for entry-level drivers. This part of the study will involve fifty-four (54) novice tractor-trailer driver students who will be trained on all units of the Professional Truck Driver Institute (PTDI) curriculum, as modified during a peer review. Students will be divided into two groups, with one group receiving conventional truck-based training and the other group receiving simulator-supplemented training. The control group will receive all behind-the-wheel (BTW) training (totaling 44 hours) in an actual vehicle, except for some limited exposure to the simulator for familiarity purposes; the experimental group will receive 66 percent of the BTW training in the simulator (30 hours) and the balance (14 hours) in the vehicle. Driver performance will be assessed, and measures will include the number of trials necessary to achieve the skill objective for each of the training lessons as well as the amount of time necessary to pass the skill unit. In addition to the requirements for instructional units, student drivers will perform two in-course driving skills tests, the Pre-Street Range Test (PSRT) and Final Examination Road Test (FERT). Both of these in-course tests have traditionally been performed in a truck. Student drivers in both the control group and the experimental group will attempt the PSRT and FERT first in a truck and then in a simulator. The ultimate criterion test for the transfer of training will be the student driver's performance on the Commercial Drivers

License (CDL) examination.

Part 2 evaluates the advanced capabilities of the simulator to replicate the more complex driving skills, such as the operation of double and triple combination vehicles, evasive maneuvers, jackknives, and driving on black ice. Simulators, with their ability to safely control the driving environment, appear to lend themselves particularly well to driving situations that are dangerous, unusual, or infrequently encountered. The objective of the advanced capabilities assessment is to "showcase" and assess the technology to determine the efficacy of simulation for training, testing, and licensing CMV drivers on these particular maneuvers and vehicle configurations. This part of the test will involve eight (8) experienced drivers and eight (8) students. Experienced drivers will have at least 15 years of professional driving experience and tenure of at least 2 years with the same carrier with no reportable accidents or citations for the past three (3) consecutive years. Novice truck drivers will be a subset of those students who participated in the conventionally trained group of the forward transfer of training (Part 1) who obtained the CDL. After drivers receive a brief orientation to the simulator, researchers will administer a general skills pre-test to establish the baseline differences between the two groups. Scores from the pre-test will be collected in the form of instructor's observations for the number of pass/fails performance on each trial. Following the pre-test, all drivers will be tested individually on four (4) defined advanced capabilities scenarios: Special Rigs (doubles and triples), Speed Management, Extreme Driving Conditions, and Emergency Maneuvers. Upon completion of the scenarios, all drivers will participate in post-test procedures similar to the pre-test. Additionally, the experienced drivers will complete a post-experiment questionnaire to determine the consistency among experienced drivers on the simulator's ability to present driving situations in a realistic and useful manner.

Part 3 is a continuation of Part 1 and will determine if simulator-based training ultimately results in reliable differences in a driver's performance over time. The student driver's post training driving record will be examined at three (3) and twelve (12) months following the completion of the CDL examination (and full-time employment as a tractor-trailer driver). Measures of on-the-job driver performance during this part of the study will include the number of crashes, the number of citations, supervisory ratings, and other measures, as deemed appropriate.

The SimVal study will provide answers to a number of questions regarding simulator-based training and subsequent performance. As published in the Research Design Report, these questions are:

1. Does simulation promote more efficient and/or effective training for completing instructional objectives?
2. What is the effect of simulation-based training on the Pre-Street Range Test (PSRT)?
3. What is the effect of simulation-based training on the Final Examination Road Test?
4. What is the amount of transfer for the simulation-based training group?
5. Can simulation adequately assess skill acquisition for basic operation and safe operating practices?
6. Does training method predict performance on the CDL?
7. Are there differences in performance on the CDL examination between drivers'

trained using simulation and those trained using conventional methods?
8. Does training method predict performance on the job?
9. Are there differences in job performance (e.g., accident rates, number of violations) between drivers trained using simulation and those trained using conventional methods?
10. Can simulation adequately assess driver ability for advanced capability skills?
11. Are there differences in driver performance between novice and experienced drivers for advanced capabilities?
12. Does CDL score predict driver performance for advanced capabilities?
13. Is there agreement among experienced drivers on the usefulness and realism of the simulator for the presentation of advanced capabilities?

In support of the SimVal study, a re-assessment of commercially-available truck simulators was performed to evaluate advances in simulator technology since the initial investigation, and to assess new systems that are available in the United States. This report updates the simulator evaluation report published in 1996. The simulator re-assessment described in this report is based on the functionalities and driving scenarios described in the aforementioned Research Design report. The completion of the re-assessment effort assures that FMCSA has more current information on commercially available truck simulators available in the United States. The information contained in this report will also be useful to those interested in truck simulators.

This report provides a detailed description of the process and findings of the truck simulator re-assessment program. Section 2 provides a description of the assessment tool used during this program. The assessment tool is derived from criteria contained within the SimVal Research Design report. This assessment tool facilitated the standardized assessment of each simulator. To perform these assessments, a multidisciplinary team of experts was convened. This Expert Team consisted of individuals with expertise in operator training, simulator use, commercial driver training and licensing, and commercial vehicle driving. Section 3 describes the individuals who participated in the Expert Team. Section 4 discusses the methodology of each simulator assessment. The results of each simulator assessment are provided in Section 5 of this report.

2.0 LITERATURE REVIEW AND SELECTION OF SIMULATORS FOR RE-ASSESSMENT AND EVALUATION

In April 1996, FHWA published a report titled "Commercial Motor Vehicle Simulation Technology to Improve Driver Training, Testing and Licensing Methods" (Carroll, Duker, and Robin, 1996). This previously published research surveyed and assessed existing truck driving simulators and assessed the feasibility of applying current and near-horizon simulation technology to the commercial driving environment. As part of the initial simulator assessment, a total of 12 simulators (6 U.S. and 6 foreign) ranging in price from $20,000 to $900,000 were assessed. Assessments were conducted by "driving" each of the simulators to assess their capability with respect to the performance criteria. Simulators were rated on whether or not the capabilities assessed were "adequate," "not adequate," or "not available." The evaluations reflected the assessment of the simulators in their stage of development at the time of the review. Manufacturer assertions regarding the future capabilities of a simulator were not included in the assessment.

Logistical and support realities of the follow-on SimVal study limited the evaluation of simulators to those available in the United States. Contractor personnel reviewed literature on commercially available truck simulators. Sources included web searches, promotional literature, and professional contacts. This process produced a master list of 23 truck simulators. This initial list of simulator candidates is presented in Table 1. Table 2 provides the final list of truck simulators for evaluation that was derived by deleting those systems in which:

- The company was no longer in business
- The simulator was not commercially available in the United States
- An operational system was not available for evaluation
- A truck configuration was not available
- The manufacturer recommended a specific model

Table 1
Master List of Truck Driving Simulators

Simulator	Manufacturer	Location	Source
AUTOSIM	AUTOSIM	Norway	www.autosim.com
AUTOSIM AS	AUTOSIM	Norway	www.sintef.com
Commercial Truck Driver	Lockheed Martin Information Systems	Orlando, FL	www.lmco.com
CyberTRUCK	Kobitec	South Africa	www.kobitec.co.za *
CyberTRUCK	DNS Business Group	Australia	www.dnsgroup.com.au *
Daimler Benz Driving Simulator	Daimler Benz	Germany	FHWA-MC-96-003
Doron L-300 HGV	Doron Precision Systems Inc.	Binghamton, NY	www.doronprecision.com
Doron L-300 VMT	Doron Precision Systems Inc	Binghamton, NY	www.doronprecision.com
Doron L-301	Doron Precision Systems Inc.	Binghamton, NY	www.doronprecision.com
Driver Training System (DTS)	FAAC Incorporated	Ann Arbor, MI	www.faac.com
DuPont TDS	DuPont Safety Services	Wilmington, DE	FHWA-MC-96-003
Iowa Driving Simulator	University of Iowa	Iowa City, IA	FHWA-MC-96-003
LVTS	Atlas	Denmark	www.stn-atlas.de
National Advanced Driving Simulator	University of Iowa	Iowa City, IA	FHWA-MC-96-003
Protectum	Unirisk	Sweden	www.unirisk.se
SafeDrive 1000	Digitran Simulation Systems	North Stonington, CT	FHWA-MC-96-003
STISIM	Systems Technology, Inc.	Hawthorne, CA	FHWA-MC-96-003
TT150	Perceptronics	Ann Arbor, MI	FHWA-MC-96-003
Truck Driver Screening Simulator	NBS Computer Assisted Testing	Fort Wayne, IN	FHWA-MC-96-003
TRUCKSIM	I*SIM	Salt Lake City, UT	www.i-sim.com
Trust 800	Thales Training and Simu lation	Tulsa, OK/ France	www.tts.thomson-csf.com
VTI	Swedish Road and Traffic Research Institute	Linkoping, Sweden	FHWA-MC-96-003
100-Roadmaster	Microseism	Sterling, VA	FHWA-MC-96-003

* Web sites not currently available

Table 2
Simulators Selected for Assessment in the Program

Simulator	Manufacturer	Location
L-300 VMT	Doron Precision Systems	Binghamton, NY
TRUCKSIM	I*SIM Corporation	Salt Lake City, UT
SafeDrive 1000	Digitran Simulation Systems	North Stonington, CT
Commercial Truck Driver	Lockheed Martin Information Systems	Orlando, FL
Driver Training System	FAAC Incorporated	Ann Arbor, MI
Trust 800	Thales Training and Simulation	Tulsa, OK / France

3.0 SIMULATOR EVALUATION EXPERT TEAM

To evaluate the truck simulators, FMCSA and the Contractor assembled a team of experts. These individuals brought specific skills in areas necessary to assess the simulators in an objective manner. Included in the team were experts in commercial driver training, simulator use and development of experimental programs on simulators, an award winning truck driver, and human factors experts. The team members were required to travel to each simulator facility as recommended by the manufacturers. The team members, their affiliation, and areas of expertise are listed in Table 3.

Table 3
CMV Simulator Evaluation Expert Team

Team Member	Affiliation	Expertise
John Pierowicz	Veridian Engineering	Program Management
Valerie Gawron, PhD	Veridian Engineering	Experimental Design, Human Factors, Human Performance Measurement
Ginger Watson, PhD	National Advanced Driving Simulator, University of Iowa	Simulator Design, Experimental Design, Training, Human Factors
Bill Nestor	Markinetics Inc.	Award-Winning Truck Driver
Wade Murphree	American Institute of Technology (AIT) Driver Training School	Commercial Driver Training

The Expert Team visited the manufacturer's sites, or locations designated by the manufacturers, to "drive" each simulator. The Expert Team used the assessment tool to review the ability of these simulators to satisfy the criteria of the Research Design. This report presents the results of the site visits and the assessment of each simulator system based on a consensus of the Expert Team.

4.0 SIMULATOR EVALUATION METHODOLOGY

A truck simulator assessment tool was developed for use by the Expert Team in the simulator evaluations. The assessment tool reflects the criteria of the Research Design Report. The functional evaluation criteria used to assess the devices were developed with the assistance of a recognized driver-training expert and then subjected to two reviews by a panel of subject matter experts in CMV driver training and simulators. The assessment tool provided a standardized format to assess simulator capabilities and driving scenarios addressed in the research design. Table 4 lists a sub-set of over 183 distinct factors contained in the assessment tool. Each simulator factor was assessed in terms of "Adequate," "Not Adequate," or "Not Available." This approach is consistent with the prior simulator assessment initiative. In this latest initiative, the assessment tool provides an area for the Expert Team's comments relative to each evaluation criteria.

During the course of this program, the Expert Team assessed the six selected simulators. During each visit the team conducted an extensive evaluation of the capabilities of the simulator with respect to the factors listed in the simulator assessment tool. Each visit was conducted at the manufacturer's facility or at a customer site recommended by the manufacturer. The site visits and evaluations were generally performed in one day. In some cases the manufacturers provided a briefing to the Expert Team as to the capabilities of the simulator. The Expert Team Program Manager addressed each group with a description the procedure that the Expert Team would follow during the assessment. The team spent on average six to eight hours "driving" in the simulator and reviewing the capabilities of the system.

The system assessments presented in this document were developed though a consensus process that included all members of the Expert Team. A consensus was arrived at through the driving of the simulator, assessing its capabilities, discussions with the manufacturer's representatives, and comments from users. Rankings of specific criteria within the Team were arrived via consensus approach. The criteria and manner of interpretation were constant through all simulator site visits. In situations where specific questions remained regarding system features and capabilities, the manufacturers or operators were requested to demonstrate specific system capabilities.

A description of each simulator is provided in Section 5 of this report. Each simulator description contains a General System Description of the system derived from materials provided by the manufacturer and Expert Team visits. In addition, photographs of the system or system features are provided with the permission of each manufacturer. A System Assessment Summary reflecting the comments of the Expert Team is provided. The evaluation forms and technical specifications for each simulator are contained in each section. The evaluation forms contain comment areas for entries describing the rationale for the team's assessment. This comment column was used to support the ranking (Adequate, Not Adequate, Not Available), or to provide additional detail of the specific factor.

Table 4
Selected Evaluation Assessment Tool Areas

Evaluation Criteria	Evaluation Factor
Vehicle Cab Environment	Cockpit controls replicated
	Horn present, functional
	Radio present, functional
	Flashers, present, functional
	Driver restraints present
Visual Scene	Scenery elements replicated
	Roadway properly replicated
	Objects such as signs (speed limit, stop signs) replicated
Mirrors, Transmission	Mirror configuration
	Trailer, roadway visible in mirrors
	Transmissions replicated
	Train proper shifting practices
Maneuvering in Restricted Quarters	Serpentine maneuvers
	Figure 8, Restricted Figure 8
	Sharp, restricted turns
	Movable traffic cones
Proficiency Development	Close quarter maneuvers
	Alley dock
	Parallel park
	Overhead clearance
Vehicle Gap Management	Crossing, passing traffic
	Changing lanes
	Vehicle headway
Speed Management	Hills
	Curves
	Turning
	Passing
Emergency Maneuvers	Blind intersection
	Slippery surfaces
	Blow out
	Payload overloading
	Steering deterioration
Training Tools	Bird's eye view
	Record/play/demonstrate
	Data storage
	Data printout

It is important to note, the re-assessment initiative was not a side-by-side comparison of each of the reviewed simulators; rather, it was an independent evaluation of the capability of these simulators to support the FMCSA SimVal Research Design based on the criteria identified in the assessment tool.

5.0 SIMULATOR DESCRIPTIONS AND EXPERT TEAM EVALUATIONS

Doron Precision Systems
L-300 VMT (Vehicle Maneuver Trainer)

Simulator Description

5.1 Simulator System: Doron L-300 VMT (Vehicle Maneuver Trainer)

Company: Doron Precision Systems
P.O. Box 400
Binghamton, NY 13902-0400
Contact: Mr. David Lindsey

Date of Site Visit: January 27- 28, 2000

Introduction:

This document describes a visit by the Expert Team to the Doron Precision Systems facilities in Binghamton, New York on January 27 and 28, 2000. The simulator evaluated in this visit was the Doron L-300 Vehicle Maneuvering Trainer (VMT). This section contains a description of the simulator, along with a copy of the evaluation form completed by the Expert Team. The evaluation form, including comments, represents the consensus of the Expert Team.

The simulator system described in this section is available commercially from Doron Precision Systems. The system reviewed has a cost of $205,000. Leasing costs for this system are contained within the technical specifications portion of this section.

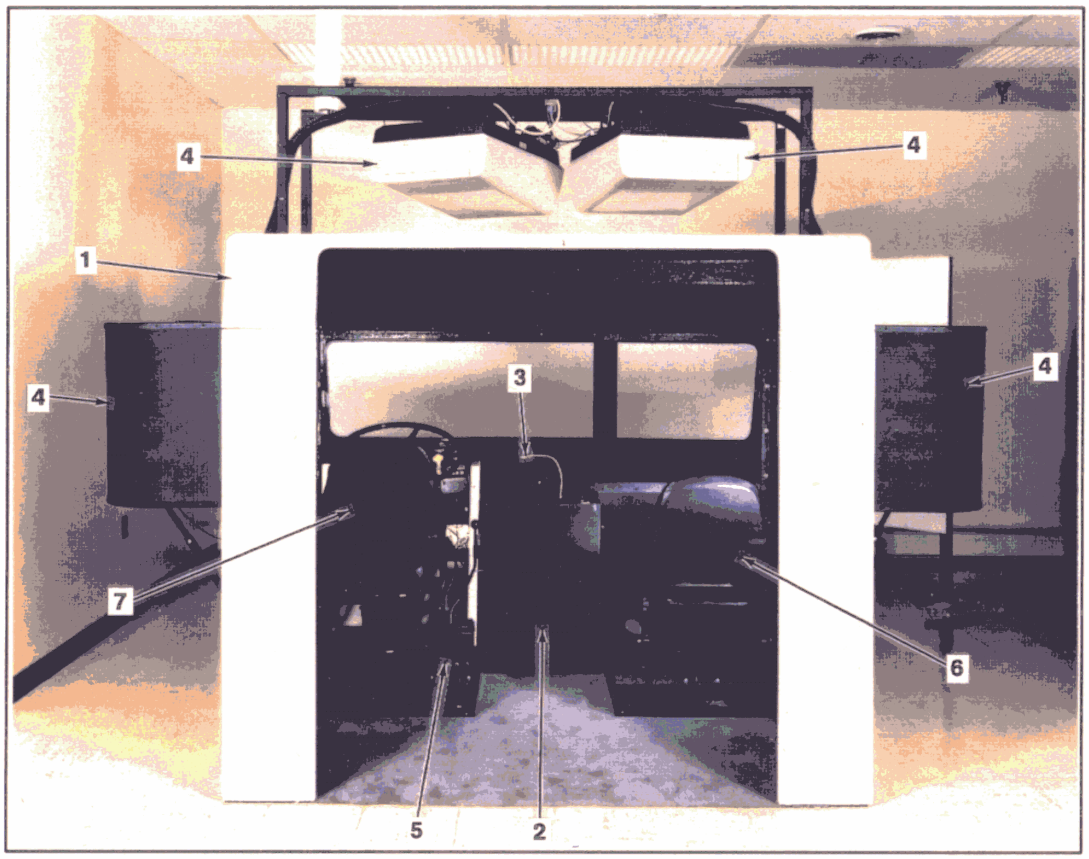
General System Description

The following general system description was developed from informational material supplied by Doron and additional information gathered by the Expert Team during the aforementioned visit. This information is used with the manufacturer's permission. The VMT is a cab and diorama-type simulator without a motion base. The VMT uses an image acquired by cameras mounted in a scale model truck operating in a diorama. A diorama is a scale-model of a roadway and building system that simulates a roadway area of approximately 700 feet x 700 feet. The driver trainee in the cab system operates the simulated trucks' controls, causing the scale model to move on the diorama. Images from the camera in the scale model truck are projected on the cab video system. The VMT is an interactive vehicle maneuvering training system that simulates an articulated commercial tractor-trailer. This system includes all controls and instrumentation to simulate a typical tractor-trailer but does not duplicate any specific make or model. The VMT is an interactive system which enables trainees to practice all basic close quarter maneuvers without the need for an instructor to be present full time. This system does not provide over-the-road training.

The Doron VMT includes the following components:

- Life size truck cab with driver and instructor/passenger stations
- Interactive video visual displays which provide eight (8) highly detailed synchronized interactive real-time displays
- Interactive life-like sound effects, engine and air brakes
- Diorama and model truck system
- Curriculum guide

The Doron VMT includes the following components illustrated in Figure 1:



Courtesy of Doron Precision Systems

Figure 1
Doron VMT Cab

1. Cab
2. Center Console and System Key Switch
3. Gooseneck Lamp
4. Cab Video Systems (projectors and screens)
5. Audio Systems
6. Instructor/Passenger Station
7. Driver Station

A description of each component is provided below:

1. Cab
   The cab is similar in shape and size to that of a late model "cab-over" tractor. There is a large opening in the front of the cab, simulating the windshield, and two small openings, one on each side of the cab, simulating the side windows. The large opening at the back of the cab enables trainees and instructor personnel to enter and exit. The driver station interior includes both a trainee's and a passenger's position. The trainee's position is equipped with components and instrumentation simulating those accessible to a driver in an actual cab.

2. Center Console and System Key Switch
   Located inside the cab, this box houses the power supply and miscellaneous electrical equipment. The main power for the system is activated by turning the system key switch that is located on top of the center console.

3. Gooseneck Lamp
   A gooseneck lamp is provided on the center console for ease of reading instruction materials.

4. Cab Video Systems
   There are two video projectors mounted securely to the top of the cab. These projectors produce images on the screens located at a specific distance in front of the cab.
   - Front View
     These images simulate a driver's view through the windshield while the driver is positioned in the driver's seat.
   - Side Views
     There is a color video monitor mounted securely to each side of the cab to simulate the view seen through each side window. The images seen on each of the monitors includes three parts. Two of these parts simulate what a driver sees in the rear view mirrors of a truck when seated in a driver's seat. The third part simulates what the driver sees out of his side window when seated in the driver's seat.

   All of the independent video images are "real time," inter-relate and are coordinated at all times with each other. There is an enclosure on each side of the cab covering each video monitor to provide for safety and security of the monitors.

5. Audio Systems
   Audio is provided to generate engine, air brakes, gear grind, road and tire noise, and gear box sounds. These sounds are audible through an amplifier and speaker heard within the interior of the cab or through headphones plugged into the rear of the transmission box. A volume control is provided to adjust the sound effects.

6. Instructor/Passenger Station
   A seat is provided adjacent to the driver station to enable either an instructor or additional student to sit in the cab and observe the trainee's performance.

7. Driver Station
   This station has all the controls to maneuver the truck model in the diorama.

8. Diorama
   The Doron VMT includes a diorama which simulates a driving range resembling an industrial area. The diorama provides the capability for performing a variety of close quarter maneuvers, such as:
   - Starting
   - Stopping
   - Straight backing
   - Backing into docks straight
   - Backing into docks offset right and left
   - Angle docking
   - Blind alley docking
   - Right and left parallel parking
   - Right and left turns at intersections
   - Backing around right and left turns

The diorama includes the following components:
- Steel structural framework is provided for strength, rigidity, and versatility
- Floors and walls are constructed of wood and plastic and finished in appropriate colors to provide realistic scenery, roadway, docks and parking areas

Scenery within the diorama is constructed primarily of wood and vacuum formed plastic and includes the following:

- Docking areas which include at least 5 straight docks, 2 angle docks, and 1 alley dock; this area also includes sufficient room to permit maneuvering the tractor- trailer into position for backing into all of the various docks
- City street area which includes parallel parking space and intersections
- Several buildings of various size, colors, and shapes
- Concrete retaining walls, brick wall and chain link fences
- Billboards, stop signs and roadway markings in appropriate locations
- One static model tractor trailer which can be parked at docks or other locations on the diorama
- One static model car that can be parked anywhere within the diorama
- Trees of various sizes, grass, and sidewalks around the buildings
- A gantry device with necessary cables to move and control the model truck; this steel constructed gantry enables free movement of the model truck on the roadways within the diorama
- A lighting system to provide even illumination throughout the diorama

- The diorama can be customized to meet the needs of the training program

9. Model Truck
   The diorama includes a scale model cab-over tractor coupled to a mock forty foot trailer. This model truck is constructed primarily of aluminum and steel for maximum reliability. The model truck's performance is fully controlled from the trainee's position in the cab portion of the system and can be driven throughout the mock roadways of the diorama.

   The truck model includes the following components:

   - Cameras mounted within the model cab. These cameras provide composite video signals to the video projectors and side-view video monitors mounted in the cab. This provides a realistic driver's perspective while driving the vehicle.
   - The front axle of the truck includes steerable wheels. The turning of these wheels corresponds to the turning of the steering wheel at the trainee's position.
   - A complete drive train is located within the truck and includes:
     – A simulated motor that is responsive to the accelerator pedal, ignition switch, and engine stop switch at the trainee's position
     – A clutch that is responsive to operation of the clutch pedal at the trainee's position
     – A transmission that is responsive to the shift lever (two forward and reverse gears) located at the trainee's position
     – A brake system that is responsive to the brake pedal, the system park brake and the protection valve located at the trainee's position
     – A differential on each of the drive axles; each axle includes its own suspension; when the operator drives over a curb, model vehicle dynamics are capable of simulating the action of a real truck (e.g., the driver feels feedback in the seat and steering wheel)
     – A fifth wheel coupling the trailer to the tractor

System Assessment Summary

The Doron L-300 VMT system is very good at the tasks for which it was designed, e.g., close quarter maneuvers, low-speed maneuvers, such as backing and docking. However, the SimVal Study calls for a more comprehensive set of available simulator functionalities. The model/diorama configuration of the Doron VMT limits the ability of the system to support the SimVal program planned by FMCSA. In addition, the Doron VMT lacks a motion base, which limits the feedback to the driver in specific situations. For example, in alley dock, the driver must use visual cues exclusively to determine if he or she has impacted the dock. The Doron VMT is available in only one configuration, as a tractor-trailer system with a cab-over. The scale model could be changed to other configurations, such as a tanker, if requested by a customer; however, the dynamics of the tanker would not be different from the tractor-trailer now modeled. The Expert Team's detailed simulator evaluation results for the Doron L-300 VMT are contained in the following section.

Doron Precision Systems
Doron L-300 VMT (Vehicle Maneuver Trainer)

Expert Team Detailed Simulator Evaluation Results

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Simulator Vehicle Cab Environment	Cockpit Controls Tachometer – Does tachometer respond to throttle application, engine sound and gear that transmission is in?	√			• Tachometer responds to throttle movement and engine sounds
	Cockpit Controls Speedometer – Does speedometer respond to visual scene, motion, engine sound?	√			• Speedometer responds to throttle application, engine sounds, and virtual scene
	Cockpit Controls Turn Signals – Are turn signals at proper location and function?	√			• Turn signals are present in the proper location and are functional
	Other Vehicle Controls - gauges Functional or mock-up. Differential lock control, oil pressure, pyrometer	√			• Functional voltmeter, oil temperature, oil pressure, air pressure, fuel level, and air reservoir pressure gauges
	Horn			√	• Present but not functional
	CB Radio			√	• Present but not functional
	Radio			√	• Present but not functional
	Emergency Flashers	√			• Fully functional
	Seat Restraint Fidelity – Does cab include three point harness?	√			• Simulator has three-point harness system
	Headlights			√	• Not available due to no night operation
	General Comments	√			• Doron VMT Simulator designed for close quarter, low-speed operation only • Cab system adequate for low-speed maneuvers for which system was designed

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Visual Scene	View out of window Are scenery elements such as buildings, hills, etc. replicated?	√			• Diorama configuration of simulator presents a limited but adequate world in which to train drivers for close-quarter maneuvers
	View out the window Is roadway replicated correctly?	√			• Diorama representation of roadway sufficient for training of close-quarter maneuvers
	View out of window Are roadside objects such as speed limit signs, stop signs, other signs properly replicated?	√			• Diorama design provides good replication of signs and buildings along roadway
Cab Mirrors	Left side of cab Is rear of trailer visible in mirror?	√			• Driver can not change perspective to rear of trailer by repositioning head to look into rear mirrors – this is used to assist depth perception • Concave and convex mirrors available on left side of cab
	Is rear view of road visible in mirror?	√			• Driver can observe rear view of road
	Is rear view of road edge visible in mirror?	√			• Driver can observe rear view of road edge
	Right side of cab Is rear of trailer visible in mirror?	√			• Driver can not change perspective to rear of trailer by repositioning head to look into rear mirrors – this is used to assist depth perception • Concave and convex mirrors available on right side of cab
	Is rear view of road visible in mirror?	√			• Driver can observe rear view of road
	Is rear view of road edge visible in mirror?	√			• Driver can observe rear view of road edge
Road Feel	Simulator at zero indicated road speed – can engine vibration be felt?			√	• No vibration provided by simulated engine
	Simulator at indicated speed – can road vibration and engine vibration be felt?			√	• No vibration provided by simulated engine and roadway – all cues are visual only
	Contact with curbs during turns	√			• Visual stimulus adequate to transmit change in vehicle orientation for curb and dock hits

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Basic Vehicle Functionality	Vehicle responds to inputs to vehicle primary controls (steering, brakes, throttle)	√			• Simulated vehicle responds well in close-quarter maneuvers
	Overhead clearance			√	
Master Basic Controls (Research Design Report Unit 1.4 NOTE: No exercise 1 in this unit)	Maneuvering in restricted quarters: Refer to Unit 1.4 "Master Basic Control" of Research Design Report for description of maneuvers	√			• Maneuvering in restricted quarters requires a different diorama configuration than presented and reviewed here • Diorama configuration can be changed by the customer to allow the scene to be set up in accordance with the maneuvers listed • Depth perception not adequate to rear of trailer – cannot use driver shift in position to change perspective on scene for backing maneuvers
	Exercise 2 (Serpentine)	√			• Able to perform serpentine in field test area
	Exercise 3 (Figure 8)	√			• Able to perform Figure 8 in field test area
	Exercise 4 (Restricted Figure 8)	√			• Able to perform restricted Figure 8 in field test area
	Exercise 5 (Turns)	√			• Able to perform turns in field test and road areas
	Exercise 6 (Restricted Turns)	√			• Able to perform restricted turns in field test area
	Exercise 7 (Sharp Turns)	√			• Able to perform sharp turns in field test area
	Exercise 8 (Combination Turns)	√			• Able to perform combination turns in field test area
	Movable Traffic Cones	√			• Traffic cones are available
	Variable Distance Setting	√			• Traffic cone distances can be changed on diorama
	General Comments	√			• Above listed maneuvers may be performed
Turning	Is road view replicated by simulator during vehicle turning maneuvers?	√			• Road view replicated accurately during turning maneuvers
	Are the vehicle dynamics of turning replicated by simulator?	√			• Very accurate dynamics on low-speed maneuvers, no high-speed turning capabilities given close quarter maneuvers

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Transmis sion Shifting (Unit 1.5)	Can simulator replicate shifting of vehicle transmission by:				
	Movement of gauge readings	√			• Gauges respond properly to gear shifting
	Shifter dynamic movement	√			• Limited number of gears given close-quarter maneuvers are replicated in transmission (reverse, first, and second gears)
	Can simulator provide practice in proper shifting practices?	√			• System can provide training of shifting technique • Vehicle will "stall" with improper shifting
Backing (Unit 1.6, examples 1-3)	Does the simulator duplicate the view out of the vehicle while transmission is in reverse and the vehicle is backing up?	√			• Shadows of vehicle moving in close proximity to loading docks provide good backing cues • Other vehicles in loading docks are replicated well
	Does the simulator duplicate the dynamics of vehicle while backing?	√			• Very accurate replication of low-speed maneuvers
	Is an overhead clearance situation possible?			√	
	Exercise 1 (Alley Dock)	√			• Alley dock maneuver can be performed adequately
	Exercise 2 (Jackknife Park)	√			• Jackknife park maneuver can be performed adequately
	Exercise 3 (Parallel Park)	√			• Parallel park maneuver can be performed adequately
Coupling and Uncoupling (Unit 1.7)	Can the simulator be aligned and backed up adequately to engage trailer kingpin?			√	• Simulator not equipped to perform this maneuver
Cones/ Pylons	Are cones or pylons available for close quarter maneuvering?			√	• Presently all close-quarter maneuvers are set-up with buildings not cones • Simulator diorama can be configured by customer to replicate close-quarter maneuvers with cones
Upgrades and	Simulator duplicates the vehicle dynamics on:				

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Downgrades	Positive (uphill) road grades			√	• No capacity to build open road scenarios in dioramas
	Negative (downhill) road grades			√	
	Mountain Driving			√	
Proficiency Development: Can simulator be set-up to perform listed maneuvers?	Close Quarter Maneuvers				
	Straight Line Backing	√			• Straight line backing can be adequately completed
	Offset Alley	√			• Offset alley maneuver can be adequately completed
	Alley Dock	√			• Alley dock maneuver can be adequately completed
	Alley Dock – Jackknifed	√			• Alley dock – jackknifed maneuver can be adequately completed
	Serpentine Forward and Reverse			√	•
	Parallel Park – Jackknifed	√			• Parallel park – jackknifed maneuver can be adequately completed
	Overhead Clearance			√	
	General Comments				• In system assessed, all close-quarter maneuvers are set-up with buildings, not cones • Simulator diorama can be customized or can be ordered by customer to replicate close-quarter maneuvers with cones
Gap Management	The simulator must be capable of simulating the length and low acceleration of CMVs to allow the students the ability to judge adequacy of gaps for passing, and entering traffic and changing lanes.				• No comments for Speed Management criteria since this simulator is used to train close-quarter maneuvers
	Crossing traffic			√	
	Passing traffic			√	

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Changing lanes			√	
	Vehicle length simulation			√	
	Vehicle acceleration			√	
Speed Management	The simulator must be capable of creating conditions requiring the driver to appropriately operate vehicle transmission, brakes and throttle in the following scenarios:				• No comments for Speed Management criteria since this simulator is used to train close-quarter maneuvers
	Hills			√	
	Curves			√	
	Slight Upgrades			√	
	Downgrades			√	
	Braking with surface texture including gravel			√	
	Parking	√			• Simulator can perform parking maneuvers
	Turning	√			• Simulator can perform turns
	Passing			√	
	Merging with traffic			√	
	Exiting from traffic			√	
	Lane Change			√	
Following Distance	The simulator must be capable of presenting the image of a lead vehicle in a way that accurately represents headway			√	• Following distance not available due to lack of other moving vehicles and close-quarter maneuver nature of simulator
Night Operation	The simulator must allow the student to be able to judge speed (relative), distance, and separation under nighttime conditions			√	• No capacity for night operation – simulated vehicle not equipped with lights

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Emergency Maneuvering (Refer to Unit 2.6)	The simulator must be capable of creating a stimulus requiring emergency braking as well as a path along which the braking must take place; e.g., vehicle pulling in path ahead, with vehicles on left and sidewalk on the right			√	• No capacity for emergency maneuvers are present in this simulator – system not designed for this capability
	Blind intersection			√	
	Slippery surfaces			√	
	Surface resistance			√	
	Black Ice			√	
	Blow out			√	
	Payload overloading			√	
	Payload poor distribution			√	
	Lack of clearance			√	
	Loose cargo brakes			√	
	Engine stalling	√			• Simulated engine will stall with selection of wrong gear
	Steering deterioration			√	
	Insecure coupling			√	
	Lane encroachment			√	
Emergency Steering (Refer to Unit 3.2)	Simulator must be able to create the sudden appearance of a stimulus in the student's path that is too close to permit the rig to be brought to a stop, but with the available lanes to permit a collision to be avoided through an evasive maneuver			√	• No capacity for emergency steering are present in this simulator – system not designed for this capability

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Brake Failure (Refer to Unit 3.2)	The simulator must be capable of defining a roadway environment in which the student must operate when the brake has failed				
	Catastrophic			√	
	Progressive			√	
Skid Recovery/ Control (Refer to Unit 2.6)	The road/traffic display must provide cues of surface friction as well as feedback to the student to indicate when the combination of speed and steering input is such to overcome the coefficient of friction			√	
Off Road Recovery	Does the simulator duplicate variation in surface from road to shoulder (refer to Unit 3.2 Exercise 3)?			√	• Vehicle can only simulate driving over curbs
Rollover	The simulator shall be capable of simulating the dynamic conditions of a rollover; negotiation of a curve at excessive speed with top heavy vehicle, trailer begins to roll before tractor			√	

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Motion Fidelity	The simulator must be capable of replicating:				
	Vibration – through displays, controls, seat, seat restraint system	√			• Motion fidelity of this simulator is adequate for the low-speed maneuvers for which it is designed
	Lateral acceleration of vehicle through maneuvers such as turning	√			• Cues are transmitted through visual stimulus only
	Longitudinal acceleration through such maneuvers as acceleration and braking	√			• Cues are transmitted through visual stimulus only
	Turbulence caused by wind gust and buffet			√	
Field of View	The simulator shall provide a field of view that includes:				
	Horizontal view from the cab	√			• Horizontal view from the cab adequate
	Vertical view from the cab	√			• Vertical view from the cab adequate
	Left view from the cab	√			• Left view from the cab adequate
	Right view from the cab	√			• Right view from the cab adequate
	Mirrors	√			• Simulation of mirrors excellent
Visual-Scene Fidelity	The texturing and shading of the simulator's visual scene shall be sufficient to duplicate:				
	Roadways	√			• Limited roadways available since system replicates terminal operations
	Traffic environments	√			• Traffic limited to parked cars
	Buildings	√			• Buildings duplicate a terminal/loading dock scene
	Pedestrians			√	
	Special zones (construction, fire house)			√	
Sound	Engine sound replicated as a function of gear noise	√			

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Engine sound replicated as a function of engine rpm	√			
	Is cab noise present, from brakes, air, other?			√	
	Is outside noise present?			√	
	Is background noise present?			√	
	Is road noise present?			√	
	Is noise from defects such as tire failure present?			√	
	Is air buzzer present during engine start?	√			
Ambient Lighting Conditions: How does the simulator replicate:	Day	√			
	Night			√	
	Dawn			√	
	Dusk			√	
	Glare			√	
Driving Stresses Fidelity	Are following traffic densities available:				
	High Density			√	
	Low Density			√	• Parked cars and tractor-trailers replicated
Task Fidelity	Actual tasks performed to operational criteria, for example, ability to use rear view mirrors in the docking maneuver of a loading bay	√			• Task fidelity is good for the close-quarter maneuvers for which this simulator was designed
Wind: Are the following wind effects available?	Speed effect on vehicle			√	
	Directional effect on vehicle			√	
	Gusts effect on vehicle stability			√	
	Directional effect on vehicle stability			√	
Desert	Are desert conditions simulated?			√	

Doron Precision Systems
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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Adverse Weather: Are the following weather conditions provided?	Rain			√	
	Snow			√	
	Slush			√	
	Ice			√	
Poor Visibility: Are the following causes of poor visibility available on simulator?	Caused by snow			√	
	Caused by sleet			√	
	Caused by ice			√	
	Caused by fog			√	
	Caused by mist			√	
	Caused by rain			√	
	Caused by dust			√	
	Caused by smoke			√	
Freeway-to-Freeway Connectors	Does the simulator provide a geometrically constrained section of roadway, such as a freeway-to-freeway connectors, or clover-leaf			√	

Doron Precision Systems
L-300 VMT

Criterion	Factor	Available	Not Available	Explanation of Rating/Comments
Tractor-Trailer Configurations	Single Trailer	√		• Only one configuration (cab-over) available
	Double Trailer		√	
	Triple Trailer		√	
	Tanker Trailer		√	

Special Rigs – Unit 1.9

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Double/Triple Trailers Dynamics	Simulator should duplicate the following characteristics of Double and Triple trailers:				
	Handling and stability			√	
	Response to steering			√	
	Sensory feedback			√	
	Braking			√	
	Oscillatory sway			√	
	Rollover in steady turns			√	
	Yaw stability in steady turns			√	
	Slow speeds on steep grades			√	
	Longer passing times			√	
	Splash and spray impacts			√	
	Aerodynamic buffeting			√	
	View blockages			√	
	Lateral placement			√	

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Tanker Vehicle Dynamics	Simulator shall replicate the following characteristics of Tanker-Trailers:				
	Effects of cargo surge on vehicle handling			√	
	Proper braking when motor vehicle is empty, full or partially full			√	
	Handling baffled/compartmental tank interiors versus non-baffled motor vehicles			√	
	Differences in cargo surge for liquids of varying product densities			√	
	Effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks			√	

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructional Features	Features to facilitate training, testing of the student driver	√			• A training program is available
Tutorial	Are training tutorials for use by the instructor provided by the simulator?	√			• Training materials are available for use by instructor on operation of system
Automated Performance Measurement	Automatic calculation of time, number of trials, and errors made by each student			√	
Scenario Control	Automatically configure and control the simulator upon instructor selection of conditions – including ability to stop, start, and reposition simulator.			√	• No automatic configure feature available, diorama must be changed manually for other training scenarios
Initial Condition Control	Instructor control over:				
	Vehicle configuration	√			• Limited number of gears (reverse, first, second gears) available in this simulator • Adequate for close-quarter maneuvers
	Roadway characteristics			√	
	Environmental conditions			√	
	Vehicle handling characteristics such as payload weight, distribution	√			• Low-speed handling adequate
Real-time Simulation Variable Control	The simulator must be capable of controlling the insertion, removal, and alteration of simulation variables while the simulator is running a scenario			√	• No capability of controlling the insertion, removal, and alteration of simulation variables, such as vehicle weight, trailer configuration while the simulator is running a scenario
Malfunction Control	Provide the instructor with the capability to preprogram a sequence of abnormal vehicle equipment conditions and/or emergency conditions before or during the training			√	
Reposition	Capability to position the simulator at any point in the training scenario			√	

Doron Precision Systems
L-300 VMT

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructor Overview	Provide the instructor with a meaningful depiction of the student performance during active training			√	
Bird's Eye View	Enable instructor to see vehicle interactions from above			√	
Freeze	Simulator provides the capability to change certain scenario characteristics while others remain constant			√	
Record/Play/ Demonstrate	Capability to record and reproduce all events, which occur as a consequence of student input to simulator's controls or instructor's demonstration			√	• Visual record of student performance can be recorded on a VCR for later replay
Data Storage	Store test data by subject/test number			√	
Data Printout	Does simulator provide printout of driver rating, errors, performance?			√	
Simulator Records	Does simulator record driver reaction times, braking distances, other factors?			√	• Simulator does not record and store driving performance records

Doron Precision Systems
L-300 VMT (Vehicle Maneuver Trainer)

Simulator Specifications/Cost Information as Provided by Manufacturer

Doron Precision Systems
L-300 VMT

Criterion	Factor	Value/Comment
Sight	Minimum number of seconds road scene is ahead of the truck, distance to the sides	Sight distance controlled by diorama. Current diorama scales to approximately 210 feet x 210 feet.
Color	Number of colors used in visual scene (e.g., 256, infinite)	Colors are limited only by time spent preparing diorama
Refresh Rate	Number of times per second visual image is refreshed	Refresh rate = 30 Hz (camera refresh rate)
Field of View	Simulator Field of View	60 degrees forward + rear view mirrors
Object Visual Fidelity	Scan lines and minutes of visual arc per object	Not applicable – no interactive traffic
Object Behavioral Fidelity	Individual objects behave autonomously and can merge, pass, speed, tailgate	Not applicable – no interactive traffic
Objects	Number of objects that can be simulated simultaneously in the visual scene	Limited to stationary objects in diorama
Lighting Fidelity	Luminance, spectral match	None
Road Fidelity	Highway	None
	Arterials	None
	Collectors	None
	On and off ramps	None
	Intersections	One intersection in diorama
	Loop	None
	Traffic Signals	None
Scene Location	Urban	Restricted to diorama setting (loading dock area)
	Rural	Restricted to diorama setting (loading dock area)
Rail Crossings	Stop when carrying specified hazardous materials	None
Engine	Types of engine simulated	Generic truck
Transmission	Types of transmissions simulated	Generic transmission – 10 speed; reverse, first, second gears active
Trailer Body	Van and enclosed body	Enclosed trailer
Axles	2- and 3-axle	3-axle tractor trailer

Doron Precision Systems
L-300 VMT

Criterion	Factor	Value / Comment
Acquisition Cost Information	Acquisition costs (as of 1/2000)	Acquisition cost = $205,000
	Operating costs (as of 1/2000)	Operating cost = two 115 VAC 20 AMP service
	Maintenance costs (as of 1/2000)	Maintenance cost = $4,500/year
Leasing Cost Information	Leasing costs (as of 1/2000)	3 year lease/purchase + $76,206/year
	Operating costs (as of 1/2000)	Operating cost = two 115 VAC 20 AMP service
	Maintenance costs (as of 1/2000)	Maintenance cost = $4,500/year
Simulator Sickness	Percent of students who experience simulator sickness	Less than 1%
User Acceptance	Feedback of simulator users on: ease of use	No information provided by manufacturer
	Cost	No information provided by manufacturer
	Sickness	No information provided by manufacturer
System Upgrades	Type of upgrades to the simulator	Proprietary information - No information provided by manufacturer
	Schedule of upgrades to the simulator	Proprietary information - No information provided by manufacturer
Reliability	Mean time between failures	Average of 2 hours maintenance four times a year
	Number of hours of down time for maintenance	Average of 2 hours maintenance four times a year
Tech Support	Availability	15 service technicians located in various states
	Cost	Tech support included in maintenance agreement
Warranties	Coverage	All parts covered in warranty
	Duration	Warranty duration = 1 year
	Cost	Cost included in maintenance agreement

I*SIM Corporation
TruckSIM Simulator

Simulator Description

5.2 Simulator System: I*SIM TruckSIM Simulator

Company: I*SIM Corporation (Now GE Capital I*SIM)
2961 W. California Ave
Salt Lake City, UT 84104
Contact: Mr. Reg Wells

Date of Site Visit: February 24, 2000

Introduction

This section describes a visit by the Expert Team to the Carnegie Mellon University (CMU) in Pittsburgh, PA to evaluate the I*SIM TruckSIM Simulator. This location was recommended by I*SIM as being representative of the TruckSIM model. The meeting was hosted by the Carnegie Mellon Research Institute. Representatives from I*SIM were present during the evaluation and assisted in answering questions and demonstrating the simulator. A description of the TruckSIM simulator is provided, along with a copy of the evaluation form completed by the Expert Team. The evaluation forms including the comments represent the consensus of the Simulator Expert Team.

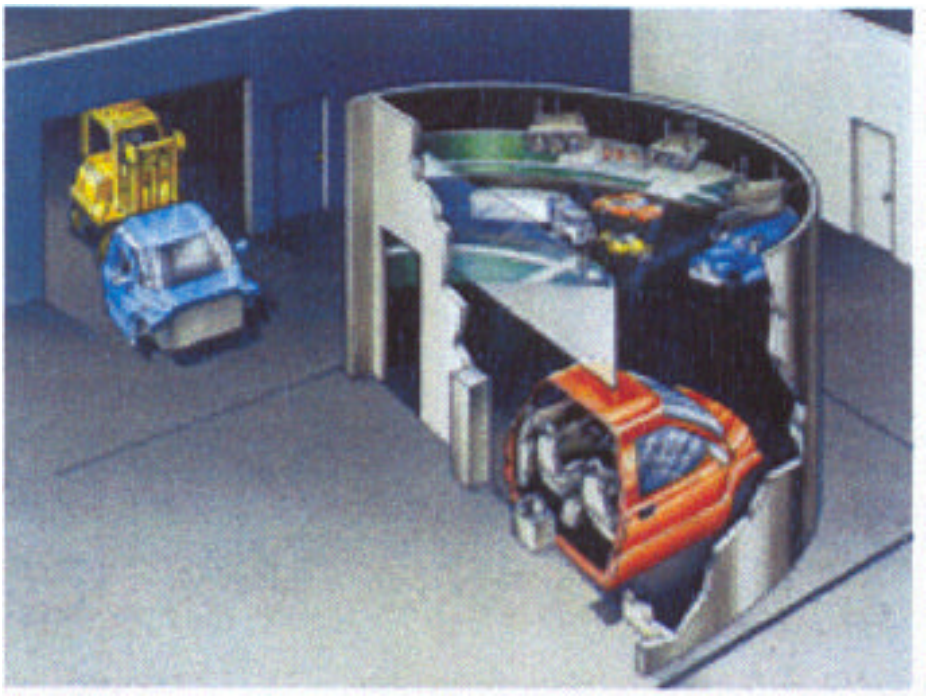
The simulator system described in this section is available commercially from I*SIM Corporation. Acquisition and leasing costs for this system are proprietary to I*SIM Corporation.

General System Description

The following general system description was developed from informational material supplied by I*SIM and additional information gathered by the Expert Team during the aforementioned visit. This information is used with the manufacturer's permission. The TruckSIM Commercial Vehicle Driving Simulator is designed to provide a realistic driving experience. The TruckSIM Simulator uses an actual truck cab enclosed in a light-tight, half cylindrical display enclosure. The visual scene is generated by three projectors mounted overhead of the cab. The projector system is not visible to the driver in the cab. The images from the projectors are reflected by a mirror onto the image screen. The screen provides for an excess of 180 degrees of visual scene.

The cab is mounted on a 6 degree-of-freedom (6 DOF) ball-screw motion platform that simulates vehicle dynamic motions. An illustration of the I*SIM TruckSIM is shown in Figure 2. The simulator cab uses the actual controls and instruments of the Freightliner vehicle, and provides a very realistic driving environment. The cab has fully operational dash instrumentation, indicators, horns and turn signals. Mirrors are duplicated by the use of LCD monitors mounted in the positions normally used by the mirrors. The monitors provide the same view as the flat rear view mirrors that the truck would provide. Figure 3 illustrates the LCD mirror simulation. No convex mirrors to facilitate vehicle backing are provided. Primary vehicle controls such as steering, brake, clutch, accelerator, and gear shift are equipped to provide force feedback to the driver.

Each of these areas is evaluated in the detailed evaluation sheets. Vibration (bandwidth >20 Hz) was implemented into the cab, seat, and steering wheel to replicate natural tactile stimulus to the driver. The simulator enables simulation of over 200 engine/transmission configurations. A closed-circuit camera mounted in the cab provides for observation of the driver from the Simulator Control Console. A digital computer generation of actual in-cab vehicle noises associated with all facets of driving is provided. Sounds normally replicated include engine noise, tires, road noise, wind, and other vehicles. All audio signals are correlated with variations in tire/roadway and engine operation.



Courtesy of I*Sim Corporation

Figure 2
I*SIM TruckSim Simulator Configuration

The TruckSIM Simulator is controlled at the Operators Console. The Operators Console is shown in Figure 4. The Operators Console uses a Windows-based point-and-click control format for all simulator functions. The console includes monitors to view all scenes visible to the driver. These monitors are illustrated in Figure 5. The upper monitors display the view of the forward scene as provided on the main viewing scene in the enclosure. The two monitors to the side display the view of the corresponding cab side mirrors. The central computer monitor provides a status of vehicle control functions such as steering angle, clutch engagement, gear, throttle position, and vehicle simulated speed.

Courtesy of I*Sim Corporation

Figure 3
Simulator Cab Illustrating LCD Mirrors

Courtesy of I*Sim Corporation

Figure 4
TruckSIM Operators Console

Control of the simulator and modification of the scenarios takes place on the Operators' Console, shown in Figure 6. This station uses a Graphical User Interface (GUI) with pull down menus to set up a simulator run. This station is also shown in Figure 5. The system allows for the selection of menu options such as: scenario types, pause, and record training event for later playback. The system can interact in real-time with moving models through changing traffic behavior, weather conditions, tire adhesion and day/night selections. Vehicle properties such as suspension characteristics, tires, vehicle weight, and type can also be controlled through the Operators Console.

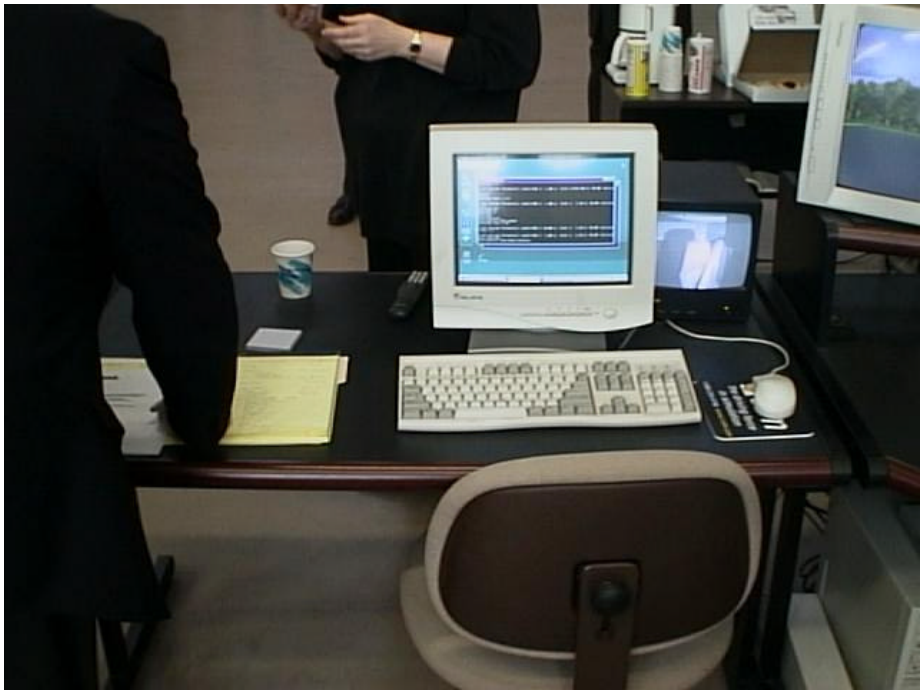
Courtesy of I*Sim Corporation

Figure 5
Simulator Cab Status Monitors

System Assessment Summary

The I*SIM TruckSIM simulator system is very good in duplicating the over-the-road visual and dynamic characteristics of a tractor-trailer. Specific deficiencies of the motion system are detailed in the assessment sheets. The vehicle cab, using an actual tractor cab, provides a very good replication of the vehicle controls and environment. The design of the mirror system provides a realistic view of the rear of the trailer and road, as well as approaching traffic. The simulator does a good job with replicating traffic and pedestrians.

The vehicle dynamic characteristics of this system were good. The modulation of the brakes in this system was notable, with the ability to use variable effort in the braking, as in "real" driving. The Expert Team was able to duplicate the dynamics of a roll-over and able to use proper control techniques to recover from these roll-over conditions.



Courtesy of I*Sim Corporation

Figure 6
Operators Console

The versatility of this system was demonstrated by the ability to quickly configure the system for specific training situations. The I*SIM team was requested to arrange a series of cones in a parking lot scenario for close-quarter maneuvers, as illustrated in Unit 1.4 of the Research Design Report. The I*SIM team completed the set-up of the scenario, and was able to allow the Expert Team to evaluate the maneuvers within 20 minutes.

The TruckSIM simulator system lacks some potentially useful training features that would facilitate training of drivers. For example, the system requires post processing of data recorded during a training sessions to assess driver performance. This results in a delay in feedback to students as to performance until the data are processed. No automated driver rating or tabulations of results is available. The Expert Team detailed simulator evaluation results for the I*SIM TruckSIM are contained in the following section.

I*SIM Corporation
TruckSIM Simulator

Expert Team Detailed Simulator Evaluation Results

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TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Simulator Vehicle Cab Environment	Cockpit Controls Tachometer – Does tachometer respond to throttle application, engine sound and gear that transmission is in?	√			• Tachometer responds correctly to throttle application
	Cockpit Controls Speedometer – Does speedometer respond to visual scene, motion, engine sound?	√			• Speedometer reacts correctly to engine sound, throttle application, and visual scene
	Cockpit Controls Turn Signals – Are turn signals at proper location and function?	√			• Real turn signals used, in proper position • Turn signals are functional
	Other Vehicle Controls - gauges Functional or mock-up. Differential lock control, oil pressure, pyrometer	√			• Gauges functional (oil pressure, fuel level, air pressure present), pyrometer not present but available upon customer request
	Horn			√	• Not available in cab – available upon request
	CB Radio	√			• Real unit used, using actual frequencies
	Radio	√			• Actual radio used
	Emergency Flashers	√			• Flashers are present and functional
	Seat Restraint Fidelity – Does cab include three point harness?	√			• Cab has three point restraints, duplicating system found in a real truck
	Headlights	√			• Headlights present, not properly adjusted to visual scene
	General Comments				• Rattling of cab structure very distracting during evaluation • Cab environment built from Freightliner day cab
Visual Scene	View out of window Are scenery elements such as buildings, hills, etc. replicated?	√			• Pedestrians are reproduced very well – convincing movement noted

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TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	View out the window Is roadway replicated correctly?	√			• Replication of roadway is good
	View out of window Are roadside objects such as speed limit signs, stop signs, other signs properly replicated?	√			• Roadside signs appear much larger than normal • Traffic lights are out of focus until very close • Roadway signs are not accurate (22 N is a designation for an east/west roadway not north/south)
	General Comments	√			• Although visual scene is adequate, following noted: -visual scene is hazy during turns -horizontal streaking in image during higher acceleration -seams in front screen are distracting
Cab Mirrors	Left side of cab Is rear of trailer visible in mirror?	√			• No convex mirrors available • During turns driver can see trailer tires in side mirrors – should only see trailer
	Is rear view of road visible in mirror?	√			• Rear view of road is visible in mirrors
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible in mirrors
	Right side of cab Is rear of trailer visible in mirror?	√			• During turns driver can see trailer tires in side mirror – should only see trailer
	Is rear view of road visible in mirror?	√			• Rear view of road is visible in mirrors
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible in mirrors
Road Feel	Simulator at zero indicated road speed – can engine vibration be felt?	√			• Engine vibration replication adequate
	Simulator at indicated speed – can road vibration and engine vibration be felt?		√		• Road and engine vibration not replicated
	Contact with curbs during turns	√			• Exaggerated, but adequate road feel on curbs (very disruptive bump)

I*SIM Corporation
TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Basic Vehicle Functionality	Vehicle responds to inputs to vehicle primary controls (steering, brakes, throttle)	√			• Vehicle responds properly to inputs to vehicle primary controls
	Overhead clearance		√		• No clearance problems on bridges; hindering overhead clearance training • Impact on "gas station overhang" not properly simulated, vehicle passes through overhang
Master Basic Controls (Research Design Report Unit 1.4 NOTE: No exercise 1 in this unit)	Maneuvering in restricted quarters: Refer to Unit 1.4 "Master Basic Control" of Research Design Report for description of maneuvers				• Listed maneuvers are not presently part of the simulator database. Simulator scenario generation toolbox allows users to set up scenarios quickly. The team requested that exercise 2 and 3, as representative of the maneuvers in this section, be set up to prove the utility and timeliness of this feature. Exercise 2 and 3 were set up, demonstrated and evaluated by team within 20 minutes – cones were placed per drawings in Unit 1.4 • Based on performance of exercises and flexibility of system, the Expert Team was satisfied other exercises can be performed
	Exercise 2 (Serpentine)	√			
	Exercise 3 (Figure 8)	√			
	Exercise 4 (Restricted Figure 8)	√			
	Exercise 5 (Turns)	√			
	Exercise 6 (Restricted Turns)	√			
	Exercise 7 (Sharp Turns)	√			
	Exercise 8 (Combination Turns)	√			
	Movable Traffic Cones	√			• Movable traffic cones available
	Variable Distance Setting	√			• Cone distances can be set by instructor easily
	General Comments				Although adequate, during turns driver should not be able to observe tires on trailer – present configuration shows tires
Turning	Is road view replicated by simulator during vehicle turning maneuvers?	√			• Although adequate, rapid movement of scene causes blurring of image
	Are the vehicle dynamics of turning replicated by simulator?	√			• Although adequate, feel of trailer over curb not consistent – different for off ramps and streets

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Transmission Shifting (Unit 1.5)	Can simulator duplicate shifting of vehicle transmission by:				
	Movement of gauge readings	√			• Movement of gauge readings adequate
	Shifter dynamic movement	√			• Shifter dynamic movement replicated well
	Can simulator provide practice in proper shifting practices?	√			• Simulator can provide practice in proper shifting practices
Backing (Unit 1.6, examples 1-3)	Does the simulator duplicate the view out of the vehicle while transmission is in reverse and the vehicle is backing up?		√		• Although generally acceptable, in this backing situation mirrors and field of view to back and side of simulator are angled up. This restricts view during backing up
	Does the simulator duplicate the dynamics of vehicle while backing?	√			• Duplication of trailer movement up a ramp, with restriction of engine power very realistic
	Is an overhead clearance situation possible?	√			
	Exercise 1 (Alley Dock)			√	
	Exercise 2 (Jackknife Park)		√		• Home repair store scenario for overhead clearance unrealistic
	Exercise 3 (Parallel Park)			√	• Not available to test
Coupling and Uncoupling (Unit 1.7)	Can the simulator be aligned and backed up adequately to engage trailer kingpin?			√	• Tractor can be configured to bob-tail mode • No tractor tires visible when backing up – critical cue during coupling • Can not back up with tractor in bob-tail configuration
Cones/Pylons	Are cones or pylons available for close quarter maneuvering?	√			• Demonstrated excellent system capability and flexibility

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TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Upgrades and Downgrades	Simulator duplicates the vehicle dynamics on:				
	Positive (uphill) road grades	√			• Vehicle will slow down on positive grades with constant throttle – good replication of actual dynamics
	Negative (downhill) road grades	√			• Vehicle will pick up speed on negative grades with constant throttle – good replication of actual dynamics
	Mountain Driving	√			• Stripped a gear during downshifting in mountain driving scenario – good sound replication
Proficiency Development: Can simulator be set-up to perform listed maneuvers?	Close Quarter Maneuvers:				• Some nausea experienced
	Straight Line Backing		√		• Depth perception to rear insufficient to perform maneuver – mirrors inadequate for this maneuver
	Offset Alley			√	
	Alley Dock			√	
	Alley Dock – Jackknifed			√	
	Serpentine Forward and Reverse		√		• Depth perception to rear insufficient to perform maneuver – mirrors inadequate for this maneuver
	Parallel Park – Jackknifed		√		• Depth perception to rear insufficient to perform maneuver – mirrors inadequate for this maneuver
	Overhead Clearance			√	• Clearance problems cannot be created
Gap Management	The simulator must be capable of simulating the length and low acceleration of CMV's to allow the students the ability to judge adequacy of gaps for passing, and entering traffic and changing lanes				
	Crossing traffic	√			• Crossing traffic replicated adequately
	Passing traffic	√			• Passing traffic adequately replicated

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TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Changing lanes	√			• There is one level of traffic aggressivity in the programmed traffic while changing lanes in proximity to the simulated vehicle
	Vehicle length simulation	√			• Vehicle length simulation replicated adequately
	Vehicle accele ration	√			• Although adequate, the tractor trailer accelerates too fast
Speed Management	The simulator must be capable of creating conditions requiring the driver to appropriately operate vehicle transmission, brakes and throttle in the following scenarios:				
	Hills	√			• Good replication of speed management during ascent of hills
	Curves	√			• Good speed management on curves
	Slight Upgrades	√			• Good speed management on slight upgrades
	Braking with surface texture including gravel		√		• Inconsistent, inadequate replication of road shoulders
	Parking	√			• Good speed management during parking
	Turning	√			• Good speed management while turning
	Passing	√			• Good speed management while passing
	Merging with traffic	√			• Good speed management merging with traffic
	Exiting from traffic	√			• Good speed management exiting from traffic
	Lane Change	√			• Good speed management during lane changes
Following Distance	The simulator must be capable of presenting the image of a lead vehicle in a way that accurately represents headway.	√			• Simulator presents a lead vehicle that may be used to represent and maintain headway
Night Operation	The simulator must allow the student to be able to judge speed (relative), distance, and separation under nighttime conditions		√		• Simulator replicates a night driving scene • There was no effect of the vehicle headlights on the visual scene during night driving

I*SIM Corporation
TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Emergency Maneuvering (Refer to Unit 2.6)	The simulator must be capable of creating a stimulus requiring emergency braking as well as a path along which the braking must take place; e.g., vehicle pulling in path ahead, with vehicles on left and sidewalk on the right	√			• Visual scene sufficient for most emergency maneuvers
	Blind intersection		√		• Inadequate – insufficient number of objects to create blind intersections
	Slippery surfaces	√			• Slippery surfaces generally adequate – see below
	Surface resistance		√		• Insufficient gravel run-off, shoulder, median
	Black Ice	√			• Effect of black ice adequate, patches of ice not available – entire section of roadway must be covered
	Blow-out	√			• Replication of tire blow-out adequate
	Payload overloading	√			• Effect of payload overloading adequate
	Payload poor distribution	√			• Effect of poor payload distribution adequate
	Lack of clearance			√	
	Loose cargo brakes			√	
	Engine stalling	√			• Simulator will stall with wrong gear/RPM
	Steering deterioration	√			• Effect of steering deterioration replicates faulty mechanism, i.e., tie rod braking
	Insecure coupling			√	
	Lane encroachment	√			• Lane encroachment by other vehicle adequate

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TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Emergency Steering (Refer to Unit 3.2)	Simulator must be able to create the sudden appearance of a stimulus in the student's path that is too close to permit the rig to be brought to a stop, but with the available lanes to permit a collision to be avoided through an evasive maneuver	√			• The simulator can provide a vehicle stopped in a multi-lane roadway to allow practice of emergency steering maneuver
Brake Failure (Refer to Unit 3.2)	The simulator must be capable of defining a roadway environment in which the student must operate when the brake has failed:				
	Catastrophic	√			• Catastrophic brake loss well replicated • JAKE brake on simulator had no effect on vehicle braking • No sound replication of air loss in brake failure
	Progressive			√	
Skid Recovery/ Control (Refer to Unit 2.6)	The road/traffic display must provide cues of surface friction as well as feedback to the student to indicate when the combination of speed and steering input is such to overcome the coefficient of friction			√	• No skidding when brakes are locked up
Off Road Recovery	Does the simulator duplicate variation in surface from road to shoulder (refer Unit 3.2 Exercise 3)?		√		• No effect on vehicle dynamic state when transitioning from road to shoulder to median
Rollover	The simulator shall be capable of simulating the dynamic conditions of a rollover; negotiation of a curve at excessive speed with top heavy vehicle, trailer begins to roll before tractor	√			• Simulator was very good in replicating the conditions of a roll-over, e.g., negotiation of a curve at excessive speed with a top-heavy vehicle • The simulator allowed the driver to use the steering, throttle, and brakes to recover from the roll-over

I*SIM Corporation
TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Motion Fidelity	The simulator must be capable of replicating:				
	Vibration – through displays, controls, seat, seat restraint system		√		• No vibration of steering or gear shift during simulator operation
	Lateral acceleration of vehicle through maneuvers such as turning	√			• Lateral acceleration fidelity of vehicle adequate
	Longitudinal acceleration through such maneuvers as acceleration and braking	√			• Braking well replicated
	Turbulence caused by wind gust and buffet		√		• No effect on vehicle path • No sound component of wind, no visual input to driver
Field of View	The simulator shall provide a field of view that includes:				
	Horizontal view from the cab		√		• Horizontal view from cab too narrow – when using the mirrors can observe end of screen
	Vertical view from the cab	√			• Vertical view from cab acceptable
	Left view from the cab		√		• See horizontal view from cab above
	Right view from the cab		√		• See horizontal view from cab above
	Mirrors		√		• Trailer tires are visible – should be hidden by trailer
Visual-Scene Fidelity	The texturing and shading of the simulator's visual scene shall be sufficient to duplicate:				
	Roadways	√			• Roadways in visual scene adequate
	Traffic environments	√			• Traffic environment in visual scene adequate
	Buildings	√			• Buildings in visual scene adequate
	Pedestrians	√			• Pedestrians in visual scene adequate
	Special zones (construction, fire house)	√			• Work zone in visual scene adequate

I*SIM Corporation
TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	General Comments				• Although visual scene fidelity adequate: -Projected images tilted to sides -Image does not extend below vehicle hood, but extends very high -Image does not extend back far enough -Image fuzzy, especially in close quarter maneuvers -Inadequate depth perception
Sound	Engine sound replicated as a function of gear noise	√			• Engine sound adequately replicated as function of gear noise
	Engine sound replicated as a function of engine RPM	√			• Engine sound adequately replicated as function of engine RPM
	Is cab noise present, from brakes, air, other?		√		• Cab noise from motion base distracting
	Is outside noise present?			√	
	Is background noise present?			√	
	Is road noise present?	√			• Road noise present
	Is noise from defects such as tire failure present?	√			• Defects noise adequate, although tire failure not available
	Is air buzzer present during engine start?			√	
Ambient Lighting Conditions: How does the simulator replicate:	Day	√			• Simulator replicates day adequately
	Night	√			• Simulator replicates night adequately
	Dawn	√			• Simulator replicates dawn adequately
	Dusk	√			• Simulator replicates dusk adequately
	Glare			√	
Driving	Are following traffic densities available:				

I*SIM Corporation
TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Stresses Fidelity	High Density		√		• Insufficient number of vehicles for high density, urban traffic environments
	Low Density	√			• Low density traffic adequate
Task Fidelity	Actual tasks performed to operational criteria, for example, ability to use rear view mirrors in the docking maneuver of a loading bay		√		• Task fidelity not adequate due to improper cues during tasks, for example: mirrors show rear tires during backing-up, but tires should not be visible during this maneuver
Wind: Are the following wind effects available?	Speed effect on vehicle		√		• No wind effect on vehicle speed noted
	Directional effect on vehicle		√		• Vehicle did not respond to 50 mph cross wind
	Gusts effect on vehicle stability		√		• No effects of gusts replicated by motion base – no yaw/ deviation of vehicle path noted
	Directional effect on vehicle stability		√		• No effects of gusts replicated by motion base – no yaw/ deviation of vehicle path noted
Desert	Are desert conditions simulated?			√	• No desert conditions simulated
Adverse Weather: Are the following weather conditions provided?	Rain		√		• No difference in vehicle feel in wet conditions
	Snow		√		• No difference in vehicle feel in snow conditions
	Slush			√	
	Ice	√			• Icy conditions replicated adequately
Poor Visibility: Are the following causes of poor visibility available on	Caused by snow	√			• Poor visibility caused by snow adequate
	Caused by sleet		√		• Poor visibility caused by sleet not well replicated by simulator
	Caused by ice			√	
	Caused by fog	√			• Poor visibility caused by fog replicated well
	Caused by mist	√			• Poor visibility caused by mist replicated well

I*SIM Corporation
TruckSim Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
simulator?	Caused by rain	√			• Although adequate: – Poor visibility caused by rain replicated adequately – Activation of windshield wiper had no effect on visual scene
	Caused by dust		√		• Dust condition not well replicated in simulator
	Caused by smoke		√		• Smoke condition not well replicated by simulator
Freeway-to-Freeway Connectors	Does the simulator provide a geometrically constrained section of roadway, such as a freeway-to-freeway connectors, or clover-leaf			√	

Criterion	Factor	Available	Not Available	Explanation of Rating/Comments
Tractor Trailer Configurations	Single Trailer	√		• Single Trailer configuration adequate
	Double Trailer	√		• No articulation in Double Trailer configuration
	Triple Trailer		√	
	Tanker Trailer	√		• Tanker Trailer configuration available

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TruckSim Simulator

Special Rigs – Unit 1.9

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Double/Triple Trailers Dynamics	Simulator should duplicate the following characteristics of double and triple trailers:				
	Handling and stability		√		• Lack of trailer articulation invalidates handling
	Response to steering		√		• Invalid steering due to lack of articulation
	Sensory feedback		√		• Sensory feedback incorrect due to lack of articulation
	Braking		√		• Braking incorrect due to lack of articulation
	Oscillatory sway		√		• Oscillatory sway incorrect due to lack of articulation
	Rollover in steady turns		√		• Rollover in steady turns incorrect due to lack of articulation
	Yaw stability in steady turns		√		• Yaw stability in steady turns incorrect due to lack of articulation
	Slow speeds on steep grades	√			• Slow speeds on steep grades adequate
	Longer passing times		√		• No difference from single trailer configuration
	Splash and spray impacts			√	• No slash and spray impacts on windshield
	Aerodynamic buffeting		√		• Inadequate buffeting effects – vehicle roll insufficient
	View blockages		√		• View blockages to rear incorrect due to lack of articulation
	Lateral placement in lane		√		• Lateral placement incorrect due to lack of articulation

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Tanker Vehicle Dynamics	Simulator shall replicate the following characteristics of Tanker Trailers:				
	Effects of cargo surge on vehicle handling		√		• Instructor can see effect of fluid slosh such as vehicle roll, but student cannot feel effect
	Proper braking when motor vehicle is empty, full or partially full		√		• No difference in braking apparent in empty, full, or partially full configurations
	Handling baffled/compartmental tank interiors versus non-baffled motor vehicles		√		• No effect felt in handling baffled/compartmental tank interiors versus non-baffled motor vehicles
	Differences in cargo surge for liquids of varying product densities		√		• No differences apparent
	Effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks		√		• No differences apparent

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructional Features	Features to facilitate training, testing of the student driver		√		• System not set-up to permit instructor/student communication • Driver cannot access instructional features
Operator's Manual	Is an operator's manual available for use by the instructor?	√			• While an operator's manual is available, no on-line training tutorials are available
Automated Performance Measurement	Automatic calculation of time, number of trials, and errors made by each student			√	• No real time calculation of time, number of trials available – must be acquired though post processing of recorded data
Scenario Control	Automatically configure and control the simulator upon instructor selection of conditions – including ability to stop, start, and reposition simulator.	√			• Configuration and control of simulator by instructor selection of conditions adequate
Initial Condition Control	Instructor control over:				
	Vehicle configuration	√			• Instructor control over vehicle configuration adequate
	Roadway characteristics	√			• Instructor control over roadway characteristics adequate
	Environmental conditions	√			• Instructor control over environmental conditions adequate
	Vehicle handling characteristics such as payload weight and distribution	√			• Instructor control over vehicle handling characteristics adequate
Real-time Simulation Variable Control	The simulator must be capable of controlling the insertion, removal, and alteration of simulation variables while the simulator is running a scenario	√			• Real time simulation variable control adequate
Malfunction Control	Provide the instructor with the capability to preprogram a sequence of abnormal vehicle equipment conditions and/or emergency conditions before or during the training	√			• Steering failure, tire blow-out available
Reposition	Capability to position the simulator at any point in the training scenario		√		• Can reposition simulator at specific points within the scenario but is cumbersome to use

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructor Overview	Provide the instructor with a meaningful depiction of the student performance during active training		√		• Instructor is separated from the student and cannot observe student's actions or habits
Bird's Eye View	Enable instructor to see vehicle interactions from above	√			• Scenario replay discrete activation available from operator's console • Bird's eye view available but only available to view in cab
Freeze	Simulator provides the capability to change certain scenario characteristics while others remain constant	√			• Freeze function adequate
Record/Play/ Demonstrate	Capability to record and reproduce all events, which occur as a consequence of student input to simulator's controls or instructor's demonstration		√		• No playback feature available • The simulator is capable of recording data from a student driver
Data Storage	Store test data by subject/test number		√		• The simulator can store data by test number for later post processing • Results not easily linked to specific driver
Data Printout	Does simulator provide printout of driver rating, errors, performance?			√	• No real time data printout available – electronic data must be post processed to acquire driver rating and errors
Simulator Records	Does simulator record driver reaction times, braking distances, other factors?			√	• Cited factors may be reconstructed from recorded data but no programs available currently to automatically acquire performance information

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Simulator Specifications / Cost Information as Provided by Manufacturer

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TruckSim Simulator

Criterion	Factor	Value/Comment
Sight	Minimum number of seconds road scene is ahead of the truck, distance to the sides	Visible to horizon. Street signs legible to greater than 150 meters in any direction
Color	Number of colors used in visual scene (e.g., 256, infinite)	Infinite: unlimited mix of Red-Green-Blue (RGB) on a pixel by pixel basis
Refresh Rate	Number of times per second visual image is refreshed	Display projectors: 60Hz Cab chassis motion: 60Hz Suspension: 240 Hz Tires: 960 Hz Scenario vehicles: 30 Hz Image generation (IG) frame rate: 30 Hz
Field of View	Simulator Field of View	Max. 210 degree Horizontal x 45 degree vertical Typical: 180 degree Horizontal x 40 degree vertical
Object Visual Fidelity	Scan lines and minutes of visual arc per object	Approximately 7.0 arc-min / pixel pair (3.5 arc-min/line) in display system (two lines, or 1 line pair, may be assumed as smallest visible object)
Object Behavioral Fidelity	Individual objects behave autonomously and can merge, pass, speed, tailgate	All moving objects have autonomous behavior controls that can be initialized in different ways, and changed dynamically during scenarios. There are three types: 1. Normal Vehicle Routes (NVR) - set patterns or point to point 2. Auto Density Routes (ADR) - recycled vehicles Recorded Routes (REC) for specific motions (such as collision-reaction motion) 3. Dynamic Control Routes (DCR) - for those vehicles whose speed and reactions are set to "intercept" own – cab or some other vehicle

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Criterion	Factor	Value/Comment
Objects	Number of objects that can be simulated simultaneously in the visual scene	Type 1: Fixed objects built into the visual driving environment. Unlimited. System is limited by the total number of polygons to be displayed - i.e., the sum of polygons contained in the sum of all visible objects in a scene. To prevent overloading, the optimum number of object-related polygons is determined empirically while designing each driving environment Type 2: Objects placed by the scenario controller for real-time control -moving objects (vehicles, pedestrians, animals): 36 objects -fixed (non-moving) models: 92 objects Total of all types: 128 objects
Lighting Fidelity	Luminance, spectral match	No manufacturer provide information
Road Fidelity	Highway	Per American Association of State Highway Traffic Organization (AASHTO), typically in freeway, rural and suburban roadways. Some diverse roadways created for alleys in city and subdivisions, as well as in parks
	Arterials	6-lane, 5-lane and 3-lane Arterials
	Collectors	No freeway-to-freeway interchange at this time
	On and off ramps	Standard on/off ramps
	Intersections	Various types, including controlled and uncontrolled
	Loop	26 miles of freeway (5 miles of suburban, about 24 urban)
	Traffic Signals	Traffic control devices (TCD) demonstrated with standard four phase cycles, but can be programmed by the user in any scenario to have any number of phases, with any duration desired for each phase. Also any TCD can be switched in real-time from/to any desired phase (green, yellow, red) by a logic event or "trigger" set up by logical conditions in the simulation.
Scene Location	Urban	Urban scenario demonstrated
	Rural	Rural scenario demonstrated

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Criterion	Factor	Value/Comment
Rail Crossings	Stop when carrying specified hazardous materials	Available upon request
Engine	Types of engine simulated	Cummins, Ford, Detroit Diesel
Transmission	Types of transmissions simulated	Over 200 engine and transmission models to chose from
Body	Van and enclosed body	Both configurations demonstrated
Axles	2- and 3-axle	Both configurations demonstrated
Acquisition Cost Information	Acquisition costs (as of 2/2000)	Mark II Truck Simulator as in reviewed configuration; but with Moog 6-DOF motion base: List price = $500K
	Operating costs (as of 2/2000)	One person/hr + electric + amortization
	Maintenance costs (as of 2/2000)	5% of list price/year beyond first year
Leasing Cost Information	Leasing costs (as of 2/2000)	Leasing available in 3, 5, 7 year packages, costs not provided
	Operating costs (as of 2/2000)	1 person/hr + electric + amortization
	Maintenance costs (as of 2/2000)	5% of list price/year beyond 1st year
Simulator Sickness	Percent of students who experience simulator sickness	Less than 1 in 20. Sample drivers in population limited to males who are professional drivers
User Acceptance	Feedback of simulator users on: Ease of use	No data provided by manufacturer
	Cost	No data provided by manufacturer
	Sickness	No data provided by manufacturer
System Upgrades	Type of upgrades to the simulator	Software upgrades have been provided with additional models and driving environments
	Schedule of upgrades to the simulator	Every six months
Reliability	Mean time between failures	95% up time with Moog motion base
	Number of hours of down time for maintenance	No data provided by manufacturer
Tech Support	Availability	On-call phone support, on-site support within 48 hours
	Cost	No data provided by manufacturer
Warranties	Coverage	No data provided by manufacturer

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Criterion	Factor	Value/Comment
	Duration	1 year, additional years available
	Cost	Additional warranty at 5% of simulator cost

Digitran Simulation Systems
SafeDrive 1000

Simulator Description

5.3 **Simulator System**: Digitran Simulation Systems SafeDrive 1000

Company: Digitran Simulation Systems - Ship Analytics International
183 Providence-New London Turnpike
North Stonington, CT 06359
Contact: Mr. Sandeep Gupte

Date of Site Visit: February 25, 2000

Introduction:

This section describes a visit by the Expert Team to the Carnegie Mellon Driver Training and Safety Institute (DTSI) in Connellsville, PA to evaluate the Digitran SafeDrive 1000 Simulator. This location was recommended by Digitran as being representative of the SafeDrive 1000 model. The meeting was hosted by the Carnegie Mellon Driver Training and Safety Institute. Representatives from Digitran were present during the evaluation and assisted in answering questions and demonstrating the simulator. A description of the Digitran SafeDrive 1000 simulator is provided, along with a copy of the evaluation form completed by the Expert Team. The evaluation form was completed by the entire Expert Team and the comments included are the consensus of the team.

The simulator system described in this section is available commercially from Ship Analytics International. The system reviewed has a cost of $425,000. Leasing costs for this system are contained within the technical specifications portion of this section.

General System Description:

The following general system description was developed from informational material supplied by Digitran and its parent company Ship Analytics and additional information gathered by the Expert Team during the aforementioned visit. This information is used with the manufacturer's permission. The SafeDrive 1000 Truck Driving Simulator simulates multiple tractor-trailer configurations and offers wrap around, real-time, photo-textured graphics, and realistic cab motion. The simulator consists of the following components:

Simulator Cab: Modeled after an actual truck, the simulator cab features realistic, working controls and instruments. The cab offers a full view of the driving environment with a windshield, right and left windows, and rear view mirrors. A view of the cab instrument panel is provided in Figure 7.

Instructor Station: The Instructor's Station is used to set up simulation exercises and record trainee performance reports. It consists of a control monitor, keyboard, and mouse for exercise start-up; a color monitor that provides the instructor with the trainee's view of the simulation session; and a laser printer for generation of performance reports.

Visual System: The simulation features high resolution, computer-generated textured graphics on a wrap around screen. Adjustable rear-view mirrors with correct perspective are also included.

Motion System: Hydraulic actuators underneath the cab provide realistic motion. The hydraulic motion system provides vibrations present under normal driving conditions, jolts during rough road driving, and motion caused by braking, accelerating, turning, and skidding.

Courtesy of Ship Analytics International

Figure 7
SafeDrive 1000 Cab Instrument Panel

Sound System: The simulator's sound system provides realistic engine, braking, and gearing sounds typical in an operating environment, as well as a variety of sounds from both inside and outside the cab.

Computer Systems:

Simulation Host Computer: The simulation host computer is a high speed machine based on Reduced Instruction Set Computer (RISC) architecture from Silicon Graphics. It executes the simulation software and controls and coordinates the interaction between other specialized computer systems like the image generator and the interface computer in real time. It also executes the GUI (Graphical User Interface) which enables the instructor to control the simulation parameters, scenarios, faults, etc.

Image Generator: The simulation uses a two channel Star Graphicon 2000/PTX series image generator that is capable of generating high resolution, photo-textured, anti-aliased, color graphics. It is also able to create effects of fog to simulate hazardous operating conditions as well as other functions like collision detection, height above terrain, visibility, environmental effects and level of detail. The complexity of the visual scene determines the configuration of the image generator. The output of the image generator is fed to CRT projectors, which in turn display the scene on high gain screens.

Simulation Interface Computer: This Intel Pentium-based computer serves as a link between the host computer and the hardware that constitute the physical system. It executes control software that sends commands to different subsystems such as audio, hydraulic motion, instrumentation, etc. It incorporates a high-speed data acquisition system that sends electronic control signals to, and receives the same from, the different peripheral hardware devices. A photograph of the Computer and Operator Control Stations is shown in Figure 8.

The SafeDrive 1000 system is housed within a 48 feet long, 8.5 feet wide, 8.8 feet tall trailer, enabling transport of the system to various training sites. This was the configuration evaluated at CMU DTSI. The trailer is insulated, and is equipped with heating and air conditioning to maintain proper temperature and humidity levels. It is self contained and requires only an external power source. The trailer is equipped with an air ride to reduce equipment wear and tear. A photograph of the trailer is presented in Figure 9.

Courtesy of Ship Analytics International

Figure 8
SafeDrive 1000 Control Station

Courtesy of Ship Analytics International

Figure 9
Digitran SafeDrive 1000 Trailer System

System Assessment Summary

The Digitran SafeDrive 1000 utilizes a cab system that provides the basic controls required by a commercial vehicle driver. The simulator uses software to replicate mirrors in the visual scene. The visual system of this simulator was adequate, with some details not well duplicated. The projected images of vehicles changing lanes in front of the simulator truck appeared to impact the simulator truck. The scenario database for this simulator has insufficient traffic, with inadequate programmable behavior, to enable this system to be used for gap and speed management training.

This simulator uses only vibration through the seat and steering wheel to duplicate cab and vehicle motion. No motion base is provided in this system. The simulator is capable of adequately duplicating the dynamics of various trailer configurations. The simulation of a tanker with varying loads, as well as effects of fluid movement in the trailer was well duplicated without a motion base. The Expert Team's detailed simulator evaluation results for the Digitran SafeDrive 1000 are contained in the following section.

Digitran Simulation Systems
SafeDrive 1000 Simulator

Expert Team Detailed Simulator Evaluation Results

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Simulator Vehicle Cab Environment	Cockpit Controls Tachometer – Does tachometer respond to throttle application, engine sound and gear that transmission is in?	√			• Tachometer responds adequately to throttle input, engine sound and gear that transmission is in
	Cockpit Controls Speedometer – Does speedometer respond to visual scene, motion, engine sound?	√			• Speedometer responds adequately to visual scene, motion, engine sounds
	Cockpit Controls Turn Signals – Are turn signals at proper location and function?	√			• Turn signals are in proper position and are functional
	Other Vehicle Controls - gauges Functional or mock-up. Differential lock control, oil pressure, pyrometer	√			• Functional replica of gauges are provided
	Horn	√			• Functional horn provided
	CB Radio	√			• Functional CB radio provided
	Radio	√			• Functional radio provided
	Emergency Flashers	√			• Functional flashers provided
	Seat Restraint Fidelity – Does cab include three point harness?	√			• Seat restraints replicated adequately
	Headlights			√	
	General Comments				• Cab is limited to instrument panel, windshield, seat, and left window door
Visual Scene	View out of window Are scenery elements such as buildings, hills, etc. replicated?		√		• Seams in visual field visible • Visuals blurry
	View out the window Is roadway replicated correctly?		√		• Roadway not adequately replicated, vehicle was able to drive on side of mountain, and through the mountain

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	View out of window Are roadside objects such as speed limit signs, stop signs, other signs properly replicated?		√		• Visual elements such as traffic signs blurry, unable to read until very close
Cab Mirrors	Left side of cab Is rear of trailer visible in mirror?		√		• Rear of trailer too blurry
	Is rear view of road visible in mirror?		√		• Double yellow line flash on and off
	Is rear view of road edge visible in mirror?		√		• Rear view of road edge too blurry
	Right side of cab Is rear of trailer visible in mirror?		√		• Rear of trailer too blurry
	Is rear view of road visible in mirror?		√		• Double yellow line flash on and off
	Is rear view of road edge visible in mirror?		√		• Rear view of road edge too blurry
	General Comments		√		• Mirrors are replicated in visual scene by software
Road Feel	Simulator at zero indicated road speed – can engine vibration be felt?		√		• No feel of engine vibration
	Simulator at indicated speed – can road vibration and engine vibration be felt?		√		• No feel of engine vibration, road vibration
	Contact with curbs during turns	√			• Good curb contact feel
Basic Vehicle Functionality	Vehicle responds to inputs to vehicle primary controls (steering, brakes, throttle)	√			• Although adequate: -Steering wheel jerks in drivers hands -Excessive amount of play in steering wheel -Brakes can be modulated well

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Overhead Clearance	√			• Scenario raises awareness about over-head clearance with presence of bridge height signs • Good perception of overhead clearance, even in mirrors • However, all roadway overpasses can be cleared – no overhead clearance problems available in scenarios
Master Basic Controls (Research Design Report Unit 1.4 NOTE: No exercise 1 in this unit)	Maneuvering in restricted quarters: Refer to Unit 1.4 "Master Basic Control" of Research Design Report for description of maneuvers				
	Exercise 2 (Serpentine)			√	
	Exercise 3 (Figure 8)			√	
	Exercise 4 (Restricted Figure 8)			√	
	Exercise 5 (Turns)			√	
	Exercise 6 (Restricted Turns)			√	
	Exercise 7 (Sharp Turns)			√	
	Exercise 8 (Combination Turns)			√	
	Movable Traffic Cones			√	
	Variable Distance Setting			√	
	General Comments				• Listed maneuvers cannot be performed in present simulator configuration without the generation of new software
Turning	Is road view replicated by simulator during vehicle turning maneuvers?	√			• Although adequate, left visuals need more field of view to permit proper perception of traffic
	Are the vehicle dynamics of turning replicated by simulator?		√		• No vehicle sway noted until vehicle rolls

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Transmission Shifting (Unit 1.5)	Can simulator duplicate shifting of vehicle transmission by:				
	Movement of gauge readings	√			• Only one transmission type simulated • Simulator took long to build engine RPMs
	Shifter dynamic movement	√			• Very sensitive to clutch brake
	Can simulator provide practice in proper shifting practices?		√		• No audio cue of revving of engine on downshift of gears • No tactile feedback to driver, such as cab shaking, when wrong gear is selected, only sound of gears grinding • Difficult to tell what gear transmission is in
Backing (Unit 1.6, examples 1-3)	Does the simulator duplicate the view out of the vehicle while transmission is in reverse and the vehicle is backing up?		√		• No convex mirrors available to assist backing maneuvers
	Does the simulator duplicate the dynamics of vehicle while backing?	√			• Good replication of docking bump
	Is an overhead clearance situation possible?			√	• No critical (lack of clearance) overhead clearance situations available for backing
	Exercise 1 (Alley Dock)		√		• Vision to back of vehicle insufficient to perform alley dock • Lane markings for alley dock too blurry
	Exercise 2 (Jackknife Park)		√		• Can not see to the back of vehicle to sufficiently perform jackknife park
	Exercise 3 (Parallel Park)	√			• Parallel park adequate
Coupling and Uncoupling (Unit 1.7)	Can the simulator be aligned and backed up adequately to engage trailer kingpin?	√			• Simulator adequately replicates coupling/uncoupling maneuver • Air lines are assumed to be automatically connected

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Cones/Pylons	Are cones or pylons available for close quarter maneuvering?	√			• Cones are available in software, but are not set up for maneuvering configurations listed in section 1.4 – would require new software
Upgrades and Downgrades	Simulator duplicates the vehicle dynamics on:				
	Uphill road grades		√		• Hard to maintain steady speed • No sensation of climbing – even in visual scene • Minimal feedback from system with positive grade of 6%
	Downhill road grades		√		• Replication of effect of downhill grade not adequate – driver had to accelerate to keep constant speed on going downhill
	Mountain Driving		√		• No mountain scenario available • Only 2%, 4%, and 6% grades available
Proficiency Development: Can the simulator be set-up to perform listed maneuvers?	Close Quarter Maneuvers		√		
	Straight Line Backing		√		• Visuals too blurry for close quarter maneuvers • Vision behind vehicle insufficient for backing maneuvers
	Offset Alley		√		• Vision behind vehicle insufficient for backing maneuvers
	Alley Dock		√		• Vision behind vehicle insufficient for backing maneuvers
	Alley Dock – Jackknifed		√		• Vision behind vehicle insufficient for backing maneuvers
	Serpentine Forward and Reverse		√		• Vision behind vehicle insufficient for backing maneuvers
	Parallel Park – Jackknifed	√			• Parallel park adequate

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Overhead Clearance	√			• Scenario raises awareness about overhead clearance with presence of bridge height signs • Good perception of overhead clearance, even in mirrors • All roadway overpasses can be cleared – no overhead clearance problems available in scenarios
Gap Management	The simulator must be capable of simulating the length and low acceleration of CMV's to allow the students the ability to judge adequacy of gaps for passing, and entering traffic and changing lanes				
	Crossing traffic		√		• Can not observe far enough down street to check traffic
	Passing traffic		√		• No behavior cues of other vehicles can be determined, i.e., vehicle decelerating to turn
	Changing lanes		√		• Vehicles change lanes in an unnatural manner, i.e., very fast with no indication prior to maneuver
	Vehicle length simulation		√		• Back of trailer too blurry to determine length
	Vehicle acceleration		√		• Vehicle feels sluggish, insufficient acceleration
Speed Management	The simulator must be capable of creating conditions requiring the driver to appropriately operate vehicle transmission, brakes and throttle in the following scenarios:				
	Hills		√		• Hard to maintain steady speeds in all speed management situations • Driver had to accelerate on downgrade to maintain constant speed
	Curves		√		• No motion cues, such as roll of cab, in curves
	Slight Upgrades	√			• Although adequate, hard to maintain steady speeds in slight upgrade scenarios

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Downgrades		√		• Driver had to accelerate on downgrade to maintain constant speed
	Braking with surface texture including gravel		√		• No difference noted in braking with different surfaces
	Parking	√			• Speed management during parking adequate
	Turning		√		• No motion cues, such as roll of cab, in turns
	Passing		√		• Insufficient traffic in scenarios; software capable of generating only 16 vehicles, not capable of placing or coordinating other vehicle actions
	Merging with traffic		√		• Controlled vehicles (computer generated vehicles) insufficient in number and behavior not realistic to permit merging with traffic
	Exiting from traffic		√		• Insufficient traffic in scenario
	Lane Change		√		• Controlled vehicles (computer generated vehicles) insufficient in number and behavior not realistic to permit lane changes
Following Distance	The simulator must be capable of presenting the image of a lead vehicle in a way that accurately represents headway		√		• Controlled vehicles (computer generated vehicles) insufficient in number and behavior not realistic to replicate headway
Night Operation	The simulator must allow the student to be able to judge speed (relative), distance, and separation under nighttime conditions			√	
Emergency Maneuvering (Refer to Unit 2.6)	The simulator must be capable of creating a stimulus requiring emergency braking as well as a path along which the braking must take place; e.g., vehicle pulling in path ahead, with vehicles on left and sidewalk on the right				
	Blind intersection		√		• No intersections with restricted sight distances
	Slippery surfaces	√			• Slippery surfaces adequate

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Surface resistance	√			• Surface resistance adequate
	Black Ice		√		• No sensation of black ice – no visual or handling cues
	Blow-out	√			• Tire blow-out adequate
	Payload overloading	√			• No difference in handling with various payloads
Emergency Maneuvering (Refer to Unit 2.6)	Payload poor distribution		√		• No difference in handling with various payload distributions
	Lack of clearance			√	
	Loose trailer brakes			√	
	Engine stalling			√	
	Steering deterioration	√			• Steering deterioration adequate
	Insecure coupling		√		
	Lane encroachment		√		• Behavior of computer generated vehicles not realistic to replicate lane encroachment
Emergency Steering (Refer to Unit 3.2)	Simulator must be able to create the sudden appearance of a stimulus in the student's path that is too close to permit the rig to be brought to a stop, but with the available lanes to permit a collision to be avoided through an evasive maneuver		√		• Controlled vehicle behavior not realistic or controlled enough to set up emergency steering scenario
Brake Failure (Refer to Unit 3.2)	The simulator must be capable of defining a roadway environment in which the student must operate when the brake have failed				
	Catastrophic	√			• Catastrophic brake failure adequate • Although tractor brakes adequate, trailer brakes did not work
	Progressive		√		• Minimal feel of progressive brake loss

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Skid Recovery/ Control (Refer to Unit 2.6)	The road/traffic display must provide cues of surface friction as well as feedback to the student to indicate when the combination of speed and steering input is such to overcome the coefficient of friction		√		• Skid recovery limited to 15 degrees of vehicle motion. Software stops when vehicle reaches this point. • No ability for driver to correct skid
Off Road Recovery	Does the simulator duplicate variation in surface from road to shoulder (refer Unit 3.2 Exercise 3)?		√		• Could only feel going over curb – no change in road feel when driving on shoulder/median
Rollover	The simulator shall be capable of simulating the dynamic conditions of a rollover; negotiation of a curve at excessive speed with top heavy vehicle, trailer begins to roll before tractor		√		• Simulator provides no cue for the driver to react to when entering conditions that would lead to a rollover • No swaying of cab; no motion or visual cues

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Motion Fidelity	The simulator must be capable of replicating:				
	Vibration – through displays, controls, seat, seat restraint system		√		• No tactile feedback through steering, gear shift, or seat
	Lateral acceleration of vehicle through maneuvers such as turning		√		• No lean/sway observed in visual scene or cab motion during turning
	Longitudinal acceleration through such maneuvers as acceleration and braking		√		• Vehicle accelerates too slowly • Although vehicle braking can be modulated, braking is not well representative of trucks
	Turbulence caused by wind gust and buffet	√			• Turbulence adequate
Field of View	The simulator shall provide a field of view that includes:				
	Horizontal view from the cab		√		• View to back of cab on left side insufficient due to image projection screen configuration
	Vertical view from the cab	√			• Vertical field of view adequate
	Left view from the cab		√		• View to left rear of cab insufficient, screens stop at 180 degrees • Can see back edge of screens
	Right view from the cab		√		• View to right rear of cab insufficient
	Mirrors	√			• Although adequate, mirrors appear too far away due to simulator configuration of projecting mirrors into visual scene
Visual-Scene Fidelity	The texturing and shading of the simulator's visual scene shall be sufficient to duplicate:				
	Roadways	√			• Visual scene representation of roadways adequate • Visual scene blurry
	Traffic environments		√		• Limited number of traffic vehicles (16), only 6 controlled
	Buildings	√			• Buildings adequate

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Pedestrians		√		• Pedestrians are stationary
	Special zones (construction, fire house)			√	• Special zones not available
Sound	Engine sound replicated as a function of gear noise	√			• Engine sound adequate • Simulator hydraulic power unit very distracting
	Engine sound replicated as a function of engine rpm	√			• Engine sound adequate
	Is cab noise present, from brakes, air, other?			√	
	Is outside noise present?			√	
	Is background noise present?			√	
	Is road noise present?			√	
	Is noise from defects such as tire failure present?	√			• Noise from defects adequate
	Is air buzzer present during engine start?	√			• Air buzzer present during engine start
Ambient Lighting Conditions: How does the simulator replicate:	Day	√			• Daytime lighting conditions adequate
	Night			√	
	Dawn			√	
	Dusk			√	
	Glare			√	
Driving Stresses Fidelity	Are following traffic densities available?				
	High Density		√		• Insufficient number of vehicles to construct high density traffic scenarios
	Low Density	√			• Low density traffic adequate

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Task Fidelity	Actual tasks performed to operational criteria, for example, ability to use rear view mirrors in the docking maneuver of a loading bay		√		• Straight line backing dynamics adequate, however, visual scene and mirrors are blurry
Wind: Are the following wind effects available?	Speed effect on vehicle	√			• Speed effect of wind adequate
	Directional effect on vehicle	√			• Directional effect on vehicle path adequate
	Gusts effect on vehicle stability		√		• No sway induced on vehicle by wind – no effect felt
	Directional effect on vehicle stability		√		• No sway induced on vehicle by wind - no effect felt
Desert	Are desert conditions simulated?			√	
Adverse Weather: Are the following weather conditions provided?	Rain			√	
	Snow			√	
	Slush			√	
	Ice			√	
Poor Visibility: Are the following causes of poor visibility available on simulator?	Caused by snow			√	
	Caused by sleet			√	
	Caused by ice			√	
	Caused by fog	√			• Poor visibility caused by fog adequate
	Caused by mist	√			• Poor visibility caused by mist adequate
	Caused by rain			√	
	Caused by dust			√	
	Caused by smoke			√	
Freeway-to-Freeway Connectors	Does the simulator provide a geometrically constrained section of roadway, such as a freeway-to-freeway connectors, or clover-leaf			√	• Freeway-to-freeway connectors not available

Criterion	Factor	Available	Not Available	Explanation of Rating/Comments
Tractor Trailer Configurations	Single Trailer	√		• Good replication of Single Trailer configuration
	Double Trailer	√		• Double Trailer configuration available
	Triple Trailer	√		• Triple Trailer configuration available
	Tanker Trailer	√		• Tanker Trailer configuration available

Special Rigs – Unit 1.9

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Double/Triple Trailers Dynamics	Simu lator should duplicate the following characteristics of double and triple trailers:				
	Handling and stability		√		• No lateral movement capacity present to judge handling and stability
	Response to steering	√			• Response to steering adequate
	Sensory feedback		√		• Mirrors to blurry for sensory feedback • No motion in system for tactile feedback
	Braking	√			• Braking adequate
	Oscillatory sway		√		• Oscillatory sway insufficient • No sway of articulated trailers
	Rollover in steady turns		√		• Simulator provides no cue for the driver to react to when entering conditions that would lead to a rollover; no swaying of cab, no motion or visual cues
	Yaw stability in steady turns		√		• Can not perform rollover in steady turns
	Slow speeds on steep grades	√			• Slow speeds on steady grades adequate
	Longer passing times			√	
	Splash and spray impacts			√	
	Aerodynamic buffeting	√			• Wind impact on vehicle path noted in visual scene
	View blockages		√		• View blockages too blurry
	Lateral placement		√		• Replication of lateral placement of articulated trailers inadequate due to lack of swaying on trailers

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Tanker Vehicle Dynamics	Simulator shall replicate the following characteristics of Tanker Trailers:				
	Effects of cargo surge on vehicle handling	√			• Effect of cargo surge on vehicle handling well replicated in visual scene
	Proper braking when motor vehicle is empty, full or partially full	√			• Effects of various load conditions good in tanker configuration
	Handling baffled/compartmental tank interiors versus non-baffled motor vehicles	√			• Effects of various load conditions good in tanker configuration
	Differences in cargo surge for liquids of varying product densities	√			• Effects of various load conditions good in tanker configuration
	Effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks		√		• No sway apparent in vehicle handling with load characteristics

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructional Features	Features to facilitate training, testing of the student driver	√			• Although adequate: – Instructional features limited to only replay and session summary sheets – Summary sheets provide data on how long driver has been driving, and virtual miles
Operator's Manual	Is an Operator's Manual available for use by the instructor	√			• Instructors manual available, no on-line manual available
Automated Performance Measurement	Automatic calculation of time, number of trials, and errors made by each student	√			• Although adequate, only most recent run of students is available – number of trials not available
Scenario Control	Automatically configure and control the simulator upon instructor selection of conditions – including ability to stop, start, and reposition simulator.	√			• Scenario control is adequate, although limited in ability to reposition simulator in scenario
Initial Condition Control	Instructor control over:	√			
	Vehicle configuration	√			• Adequate but limited number of options
	Roadway characteristics	√			• Adequate but limited number of options
	Environmental conditions	√			• Adequate but limited number of options
	Vehicle handling characteristics such as payload weight, distribution	√			• Adequate but limited number of options
Real-time Simulation Variable Control	The simulator must be capable of controlling the insertion, removal, and alteration of simulation variables while the simulator is running a scenario	√			• Real time simulation variable control adequate
Malfunction Control	Provide the instructor with the capability to preprogram a sequence of abnormal vehicle equipment conditions and/or emergency conditions before or during the training	√			• Malfunction control limited to tire blowout and brake failure

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Reposition	Capability to position the simulator at any point in the training scenario	√			• Can reposition simulator only at pre-selected locations in the scenario
Instructor Overview	Provide the instructor with a meaningful depiction of the student performance during active training		√		• Only a print-out of current training session available • No means of archiving of previous session results
Bird's Eye View	Enable instructor to see vehicle interactions from above	√			• Driver required to see replay at same time as instructor
Freeze	Simulator provides the capability to change certain scenario characteristics while others remain constant		√		• Simulator "Freeze" function requires that the simulation be stopped, and restarted from only a specific, pre-selected spot in the scenario • Although available, feature is limited in scope and cumbersome to use
Record/Play /Demonstrate	Capability to record and reproduce all events, which occur as a consequence of student input to simulator's controls or instructor's demonstration		√		• Ability to record and play data is available, but there is no replay or demonstration of driver's errors available • Replay function available, but must run through entire scenario, reducing usefulness of this function
Data Storage	Store test data by subject / test number	√			• Stores only most recent training session
Data Printout	Does simulator provide printout of driver rating, errors, performance?	√			• Although adequate - Only printout of most recent training session available - No flexibility to add instructor ratings - No performance assessment available
Simulator Records	Does simulator record driver reaction times, braking distances, other factors?			√	• Simulator records for driver reaction time and braking distances not available

Digitran Simulation Systems
SafeDrive 1000

Simulator Specifications / Cost Information as Provided by Manufacturer

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	Factor	Value / Comment
Sight	Minimum number of seconds road scene is ahead of the truck, distance to the sides	Information not provided by manufacturer
Color	Number of colors used in visual scene (e.g., 256, infinite)	24 bit
Refresh Rate	Number of times per second visual image is refreshed	Refresh rate = 60 Hz
Field of View	Simulator Field of View	180 degree horizontal 60 x 40 front, 60 x 30 sides
Object Visual Fidelity	Scan lines and minutes of visual arc per object	1024 x1024 scan lines front 2.5 minutes; side 3.1 minutes
Object Behavioral Fidelity	Individual objects behave autonomously and can merge, pass, speed, tailgate	Simulator capable of individual objects that behave autonomously and can merge, pass, speed, tailgate
Objects	Number of objects that can be simulated simultaneously in the visual scene	Up to 26 pre-programmed traffic vehicles; 3 vehicles instructor controlled
Lighting Fidelity	Luminance, spectral match	300 lumen CRT projectors
Road Fidelity	Highway	Available
	Arterials	Not available
	Collectors	Not available
	On and off ramps	Available
	Intersections	Available
	Loop	Available
	Traffic Signals	Available
Scene Location	Urban	Available
	Rural	Available
Rail Crossings	Stop when carrying specified hazardous materials	Not available
Engine	Types of engine simulated	Detroit Diesel, CAT, Cummings
Transmission	Types of transmissions simulated	9 speed Eaton

Digitran Simulation Systems – Ship Analytics
SafeDrive 1000 Simulator

Criterion	**Factor**	**Value / Comment**
Trailer Body	Van and enclosed body	Van and enclosed body tractor trailer available
Axles	2- and 3-axle	2-and 3-axle configurations available
Acquisition Cost Information	Acquisition costs	Acquisition Cost = $425,000
	Operating costs	One man-year for operation/maintenance
	Maintenance costs	Maintenance costs = $12,000/year
Leasing Cost Information	Leasing costs	Leasing costs = $18,000/year
	Operating costs	One man-year for operation/maintenance
	Maintenance costs	Maintenance costs = $12,000/year
Simulator Sickness	Percent of students who experience simulator sickness	Less than 10%
User Acceptance	Feedback of simulator users on: ease of use	Ease of use reported as excellent
	Cost	No information provided by manufacturer
	Sickness	Less than 10%
System Upgrades	Type of upgrades to the simulator	No information provided by manufacturer
	Schedule of upgrades to the simulator	No information provided by manufacturer
Reliability	Mean time between failures	Mean time between failures = 6 months
	Number of hours of down time for maintenance	Hours down for maintenance = 1-2, with 8 hours preventative maintenance
Tech Support	Availability	7 days a week, 24 hours a day
	Cost	No information provided by manufacturer
Warranties	Coverage	No information provided by manufacturer
	Duration	One year warranty standard, extended available
	Cost	$12,000/year

Lockheed Martin Information Systems
Millennium Driver Trainer Simulator

Simulator Description

5.4 **Simulator System**: Lockheed Martin Millennium Driver Trainer Simulator

Company: Lockheed Martin Information Systems
12506 Lake Underhill Road
Orlando, FL 32825
Contact: Mr. John Sullivan

Date of Site Visit: May 2, 2001

Introduction

This section describes a visit by the Expert Team to the facilities of Werner Enterprises in Omaha, Nebraska on May 2, 2001. The Werner location was recommended by Lockheed Martin as a representative of the Lockheed Martin Millennium Driver Trainer Simulator. A description of the simulator is provided, along with a copy of the evaluation form completed by the Expert Team. The evaluation form was completed by the entire Expert Team and the comments included are the consensus of the Team.

The simulator system described in this section is available commercially from the Lockheed Martin Information Systems. The system reviewed has a cost of $750,000. Leasing costs for this system are contained within the technical specifications portion of this section.

General System Description

The following general system description was developed from informational material supplied by Lockheed martin Information Systems and additional information gathered by the Expert Team during the aforementioned visit. This information is used with the manufacturer's permission. The Lockheed Martin Millennium Driver Trainer Simulator (DTS) provides the ability to train drivers in the operation of various wheeled or track vehicle types. The simulator is also designed to provide a training program that offers automated data collection, evaluation and scoring, realistic and accurate performance feedback, and automated adaptive student progression based on demonstrated performance. The simulator is also designed for training the specific procedures and skills required to safely operate a tractor-trailer. The gages and controls simulated in the driving cabin provide the cues required to perform these tasks. Correlated aural cues and varying visibility conditions are provided. The generated visual scene provides the essential cues required by the student to assess vehicle position and velocity, characteristics of the terrain, and other information necessary to drive his or her own vehicle in training scenarios. Sufficient detail is available to enable the student to visually assess vehicle and terrain conditions and to safely operate his or her own vehicle using approved control techniques. In addition to normal operation, the DTS also replicated emergency driving scenarios. Training scenarios are designed to simulate virtually all the expected driving conditions in the real world. A set of preprogrammed and free-run scenarios are provided to teach both basic and advanced driving skills. A photograph of the DTS is shown in Figure 10. Note that the image screens and light proof enclosure are removed.

The DTS consists of the following major hardware components:

Driver Cabin**:** Simulates the physical and functional fidelity of the interior configuration (vehicle control, equipment location, and physical movement restriction) of the driver position. The driver cabin is purchased from the vehicle manufacturer, in this example, Freightliner, to ensure accurate simulation and is then integrated with the remaining DTS subsystems. The simulator tested uses the cab from a Freightliner Century Class Vehicle. This series is a conventional day cab vehicle.

Courtesy of Lockheed Martin Corporation

Figure 10
Lockheed Martin Simulator Shown without Projection Screens

Figure 11 illustrates the instrument cluster with the text message center.

Instructor/Operator Station: Provides the instructor with information/displays and controls required to effectively control and monitor driver performance. This is illustrated in Figure 12.

Courtesy of Lockheed Martin Corporation

Figure 11
Instrument Panel in Simulator

Courtesy of Lockheed Martin Corporation

Figure 12
Instructor / Operator Station

Image display subsystem: Provides the imagery depicting the training environment as viewed by the driver. Figure 13 illustrates the Image Display Screens on the simulator.

Computer image generator: Provides the video that results in a color visual presentation for both the forward and rear-view mirror scenes, using real-time computer image generation technology.

Figure 13
Lockheed Martin Simulator
Illustrating Projection Screens

Courtesy of Lockheed Martin Corporation

Computation subsystem: Includes the hardware and software required to simulate the vehicle characteristics that respond to the driver actions and the software that defines the training exercises and evaluates the driver performance in response to these training exercises.

Aural cue subsystem: Provides the aural simulation of the training environment, including vehicle sounds and external environment sounds.

Communication subsystem: Provides the means for communication between the instructor and the driver.

Motion subsystem: Consists of a motion platform with six degrees of freedom (roll, pitch, yaw, heave, surge, and sway) and associated electrical subsystems to enhance the simulation of real world driving.

System Assessment Summary

The Lockheed Martin DTS uses a complete vehicle cab for its simulator. This provides a good basis for the simulator. A full hexapod type motion base is used in the simulator to replicate over the road dynamics. The dynamic motion of the simulator was good overall, however, an exaggerated pitching motion on the cab caused by the motion base when accelerating from a stationary position was noted as undesirable. The mirror system used in this system was very good, even replicating convex mirrors. It enabled the driver to move forward in the seat to slightly change perspective during backing maneuvers. This enhanced driver perception when backing-up. The mirrors provided a good view of the rear of the trailer and roadway. This system provided a training scenario for alley dock maneuvers. It required the driver to select a proper space with sufficient room in which to back the vehicle and enabled training for the use of the mirrors in these maneuvers. However, maintaining accurate depth perception using the mirrors was difficult, causing a low speed "impact" into the loading dock.

The simulator was set up well to perform close quarter maneuvers, however, some maneuvers were difficult to complete in the system. This difficulty was caused by the use of a 53-foot trailer as a standard configuration for this customer, and therefore, in the simulator. The close-quarter maneuvers as designed in the Research Design Report were set up to be performed with a 48-foot trailer. The additional length of the simulated trailer was most pronounced in the restricted turns and restricted Figure 8 maneuvers. It should be noted that the driver was able to perform the other close quarter maneuvers in the simulator in spite of the 53-foot trailer configuration.

The system had good replication of turn signals and warning flashers; both were visible in the rear-view mirror, as would be observed in a real truck. Headlight replication and the associated effects of the headlights in various weather conditions were well replicated.

The visual scene provided by the simulator was generally very good. Buildings were well replicated and roadside objects well detailed. The roadway was well replicated, however, the center line appeared to be very wide at a distance and shrunk to proper size as the simulator proceeded

down the "road." A number of the roadway signs appeared to be floating in mid-air, without a sign post. Simulator training tools are available and enable a student to be put in various situations where he or she may be trained to react properly. The DTS system is capable of simulating a number of different tractor-trailer configurations, for example a tanker trailer. The system tested, and described in this report, utilizes a simulated 53-foot trailer as the standard configuration. A 48-foot trailer is available from the manufacturer, but was not evaluated. The Expert Team's detailed simulator evaluation results for the Lockheed Martin Millennium Driver Training System are contained in the following section

Lockheed Martin Information Systems
Commercial Truck Driver Simulator

Expert Team Detailed Simulator Evaluation Results

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Simulator Vehicle Cab Environment	Cockpit Controls Tachometer – Does tachometer respond to throttle application, engine sound and gear that transmission is in?	√			• Tachometer adequately responds to throttle • Slow, but adequate response to downshifting of gears
	Cockpit Controls Speedometer – Does speedometer respond to visual scene, motion, engine sound?	√			• Speedometer responds adequately to visual scene, motion, and engine sound
	Cockpit Controls Turn Signals – Are turn signals at proper location and function?	√			• Turn signals are actual signals in proper location • Signals may be observed in rearview mirrors when activated
	Other Vehicle Controls - gauges Functional or mock-up. Differential lock control, oil pressure, pyrometer	√			• Gauges are functional and include: voltmeter, oil pressure, oil temperature, transmission temperature, air pressure, turbo pressure, differential lock control, pyrometer • Text only display for these functions also included on dash
	Horn	√			• Actual horn is used
	CB Radio			√	
	Radio	√			• Radio uses actual installed radio, no sound was noted from radio
	Emergency Flashers	√			• Emergency flashers are functional, and can be observed flashing in rearview mirrors
	Seat Restraint Fidelity – Does cab include three point harness?	√			• Standard three point restraint system as found in vehicle is used
	Headlights	√			• High and low beam headlights are included, good replication of beam pattern and effects in rain, fog, and snow
	General Comments	√			• Simulator cab constructed from full Freightliner day cab system with all basic controls; system duplicates real-world cab well; all equipment well integrated • Only visible sign is camera in upper right segment of cab and microphone in overhead console

Lockheed Martin Information Systems
Millennium Driver Trainer Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Visual Scene	View out of window Are scenery elements such as buildings, hills, etc. replicated?	√			• Buildings are well replicated. Buildings are sharp, and detailed • Hills and valleys are well represented, with the ability to "see over" the edge of the hill • Sharp replication of roadway elements such as light poles • Good mix of road scenes, highway, city, mountain
	View out the window Is roadway replicated correctly?	√			• Although adequate, centerline at distance appears wide, shrinks to "correct proportion" as vehicle approaches • The roadway is well replicated
	View out of window Are roadside objects such as speed limit signs, stop signs, and other signs properly replicated?	√			• Although adequate: -Most signs appear very close; a few were not readable until vehicle was very close -Some signs appear to float in air due to visual scene layering
Cab Mirrors	Left side of cab Is rear of trailer visible in mirror?	√			• Rear of trailer is visible in mirrors • Tires are visible and can be observed to rotate; well replicated
	Is rear view of road visible in mirror?	√			• Rear view of road is visible in mirrors; well replicated
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible in mirrors; well replicated
	Right side of cab Is rear of trailer visible in mirror?	√			• Rear of trailer is visible in mirrors • Tires are visible and can be observed to rotate; well replicated
	Is rear view of road visible in mirror?	√			• Rear view of road is visible in mirrors; well replicated
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible in mirrors; well replicated

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	General Comments	√			• Mirror replication excellent, including flat and convex mirrors; can change drivers perspective of scene by moving forward in seat • Mirrors can be repositioned from within the cab • Road and shoulder well replicated in mirror; this permits proper observation of vehicle position in lane, on shoulder, or in backing maneuvers
Road Feel	Simulator at zero indicated road speed – can engine vibration be felt?		√		• Simulator does not adequately replicate engine vibration in the cab while idling
	Simulator at indicated speed – can road vibration and engine vibration be felt?	√			• Road vibration is transmitted through the motion base and steering • While in motion "engine" and "road" vibration can be felt
	Contact with curbs during turns	√			• Contact with curbs well replicated by movement of cab (motion base) and feedback through steering
	General Comments	√			• Good replication of road feel and contact with curbs • Simulator does not adequately replicate engine vibration while idling
Basic Vehicle Functionality	Vehicle responds to inputs to vehicle primary controls (steering, brakes, throttle)	√			• Vehicle responds well to inputs to basic controls
	Overhead clearance	√			• Overhead clearance available in many scenarios such as bridges, tunnel, and gas station overhangs
Master Basic Controls (Research Design Report Unit 1.4 NOTE: No exercise 1 in	Maneuvering in restricted quarters: Refer to Unit 1.4 "Master Basic Control" of Research Design Report for description of maneuvers				
	Exercise 2 (Serpentine)	√			• Good replication of exercise configuration, and quick set up by instructor
	Exercise 3 (Figure 8)	√			• Good replication of exercise configuration, and quick set up by instructor

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
this unit)	Exercise 4 (Restricted Figure 8)	√			• Good replication of exercise configuration, unable to successfully maneuver 53-foot trailer through course designed for 48-foot trailer • 48-foot trailer available, but not evaluated
	Exercise 5 (Turns)	√			• Good replication of exercise configuration, and quick set up by instructor
	Exercise 6 (Restricted Turns)	√			• Good replication of exercise configuration, unable to successfully maneuver 53-foot trailer through course designed for 48-foot trailer • 48-foot trailer available, but not evaluated
	Exercise 7 (Sharp Turns)	√			• Good replication of exercise configuration, unable to successfully maneuver 53-foot trailer through course designed for 48-foot trailer • 48-foot trailer available from manufacturer, but not included in system evaluated
	Exercise 8 (Combination Turns)	√			• Good replication of exercise configuration, unable to successfully maneuver 53-foot trailer through course designed for 48-foot trailer • 48-foot trailer available from manufacturer, but not included in system evaluated
	Movable Traffic Cones	√			• Cones are available and are adequate, will fall over when hit • It was noted that cones were different colors in the right side mirrors – convex showed a mustard color cone, while the flat mirror showed a red cone • Different color cones not present in left mirrors
	Variable Distance Setting	√			• Cone distances may be changed on the fly by the instructor • Cones repositioned prior to exercise to illustrate variable distance capability
	General Comments	√			• All exercises are set up on a “range” test area • Cones are set up to demarcate the maneuver area

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Turning	Is road view replicated by simulator during vehicle turning maneuvers?	√			• The view of the road is well replicated during turning maneuvers
	Are the vehicle dynamics of turning replicated by simulator?	√			• The vehicle dynamics of turning are well replicated in the simulator
Transmission Shifting (Unit 1.5)	Can simulator duplicate shifting of vehicle transmission by:				
	Movement of gauge readings	√			• Simulator does a good job of duplicating operation of tachometer/speedometer when transmission is being shifted
	Shifter dynamic movement	√			• Shifter feel, gear engagement very good • Only one transmission provided (Eaton Super 10) in this simulator, per customer specification
	Can simulator provide practice in proper shifting practices?	√			• The simulator can provide practice in proper shifting techniques similar to a part task trainer • System provides a scoring of shifting errors with a print-out that illustrates missed shifts, gear grinding and other features
Backing (Unit 1.6, examples 1-3)	Does the simulator duplicate the view out of the vehicle while transmission is in reverse and the vehicle is backing up?	√			• The simulator duplicates the view out of vehicle while transmission is in reverse and vehicle is backing up • Although adequate, lack of depth perception hampers precision placement and precision stopping of the vehicle in backing scenarios
	Does the simulator duplicate the dynamics of vehicle while backing?	√			• The simulator duplicates the dynamics of the vehicle while backing
	Is an overhead clearance situation possible?	√			• Overhead clearance available in many scenarios such as bridges, tunnel, and gas station overhangs
	Exercise 1 (Alley Dock)	√			• Able to perform alley dock, although lack of sufficient depth perception to rear made task difficult
	Exercise 2 (Jackknife Park)	√			• Able to perform jackknife park • Lack of sufficient depth perception less critical in this maneuver

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Exercise 3 (Parallel Park)	√			• Able to perform parallel park • Lack of sufficient depth perception less critical in this maneuver
Coupling and Uncoupling (Unit 1.7)	Can the simulator be aligned and backed up adequately to engage trailer kingpin?			√	
Cones/Pylons	Are cones or pylons available for close quarter maneuvering?	√			• Cones may be placed in various configurations and distances • Distances are variable and can be changed on the fly by instructor
Upgrades and Downgrades	Simulator duplicates the vehicle dynamics on:				
	Uphill road grades	√			• Simulator duplicates the decay in vehicle speed as the vehicle proceeds up a positive grade
	Downhill road grades	√			• Simulator duplicates the increase in vehicle speed as the vehicle proceeds down a negative grade
	Mountain Driving	√			• Mountain driving is available and adequate
Proficiency Development: Can simulator be set-up to perform listed maneuvers?	Close Quarter Maneuvers	√			• Close quarter maneuvers are available and adequate • Lack of depth perception causes a use of other cues, e.g., other vehicles at loading dock for depth perception aids
	Straight Line Backing	√			• Straight line backing maneuvers are available and adequate
	Offset Alley	√			• Offset alley maneuvers are available and adequate
	Alley Dock	√			• Alley dock maneuvers are available and adequate
	Alley Dock – Jackknifed	√			• Alley dock–jackknifed maneuvers are available and adequate
	Serpentine Forward and Reverse	√			• Serpentine maneuvers are available and adequate
	Parallel Park – Jackknifed	√			• Parallel park–jackknifed maneuvers are available and adequate
	Overhead Clearance	√			• Overhead clearance available in multiple scenarios such as bridges, tunnel and gas station overhangs

Lockheed Martin Information Systems
Millennium Driver Trainer Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Gap Management	The simulator must be capable of simulating the length and low acceleration of CMV's to allow the students the ability to judge adequacy of gaps for passing, and entering traffic and changing lanes	√			• Simulator replicates the length and low acceleration of CMVs to enable driver the ability to judge adequacy of gaps for passing, entering traffic, and changing lanes
	Crossing traffic	√			• Adequate crossing traffic is available in city scenario
	Passing traffic	√			• Adequate passing traffic is available in city, highway, and mountain scenarios
	Changing lanes	√			• Adequate ability to change lanes is available in city, highway, and mountain scenarios
	Vehicle length simulation	√			• Vehicle length for 53-foot trailer is well duplicated • Enables training in proper visual outlook and scanning for lane change maneuvers
	Vehicle acceleration	√			• Vehicle acceleration well duplicated
Speed Management	The simulator must be capable of creating conditions requiring the driver to appropriately operate vehicle transmission, brakes and throttle in the following scenarios:				
	Hills	√			• The simulator is capable of creating conditions requiring students to shift gears for ascending and descending hills • Proper vehicle dynamics replicated in vehicle speed reduction/increase
	Curves	√			• The simulator creates conditions requiring students to shift gears for ascending upgrades
	Slight Upgrades	√			• The simulator creates conditions requiring students to shift gears for slight upgrades • Proper vehicle dynamics replicated in vehicle speed reduction

Lockheed Martin Information Systems
Millennium Driver Trainer Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Downgrades	√			• The simulator creates conditions requiring students to shift gears for downgrades • Proper vehicle dynamics replicated in vehicle speed increase • "JAKE" brake is operational and well replicated • Provides additional braking effort in downhill scenarios as in a real truck
	Braking with surface texture including gravel	√			• The simulator creates conditions requiring students to brake on gravel such as roadway shoulders, run-away truck ramps
	Parking	√			• The simulator creates conditions requiring students to park the vehicle
	Turning	√			• The simulator creates conditions requiring students to shift gears for turns
	Passing	√			• The simulator creates conditions requiring students to shift gears for passing traffic in city, highway, and mountain scenarios
	Merging with traffic	√			• The simulator creates conditions requiring students to merge with traffic in city, highway, and mountain scenarios
	Exiting from traffic	√			• The simulator creates conditions requiring students to exit from traffic in city, highway, and mountain scenarios
	Lane Change	√			• The simulator creates conditions requiring students to change lanes in city, highway, and mountain scenarios
Following Distance	The simulator must be capable of presenting the image of a lead vehicle in a way that accurately represents headway	√			• The simulator presents the image of a lead vehicle in a way that accurately represents headway
Night Operation	The simulator must allow the student to be able to judge speed (relative), distance, and separation under nighttime conditions	√			• Good replication of low and high beam headlights available

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Emergency Maneuvering (Refer to Unit 2.6)	The simulator must be capable of creating a stimulus requiring emergency braking as well as a path along which the braking must take place; e.g., vehicle pulling in path ahead, with vehicles on left and sidewalk on the right				
	Blind intersection	√			• Multiple blind intersections available in city scenario
	Slippery surfaces	√			• Slippery surfaces available caused by rain, snow, and slush
	Surface resistance	√			• Simulator can adequately replicate the vehicle handling capabilities experienced in rain, snow and slush
	Black Ice	√			• Black ice available and well replicated by visual and motion cues
	Blow-out	√			• Tire blow-out is well replicated by visual, motion, and sound effects
	Payload overloading			√	• Expert Team not able to evaluate capability; not available on this system due to customer requirements
	Payload poor distribution			√	• Expert Team not able to evaluate capability; not available on this system due to customer requirements
	Lack of clearance	√			• Multiple scenarios available
	Loose trailer brakes			√	
	Engine stalling	√			• Well replicated and can be induced by improper gear/ engine RPM
	Steering deterioration	√			• Effects well replicated
	Insecure coupling			√	
	Lane encroachment	√			• Lane encroachment by another vehicle available and well replicated in highway scenario • Not available in city and mountain scenarios

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Emergency Steering (Refer to Unit 3.2)	Simulator must be able to create the sudden appearance of a stimulus in the student's path that is too close to permit the rig to be brought to a stop, but with the available lanes to permit a collision to be avoided through an evasive maneuver	√			• The simulator is able to create the sudden appearance of a vehicle in the student's path that is too close to permit the rig to be brought to a stop, but with available lanes to permit a collision to be avoided through an evasive maneuver
Brake Failure (Refer to Unit 3.2)	The simulator must be capable of defining a roadway environment in which the student must operate when the brake have failed				
	Catastrophic	√			• Catastrophic failure of brakes well replicated • Dynamics adequately replicated
	Progressive			√	
Skid Recovery/ Control (Refer to Unit 2.6)	The road/traffic display must provide cues of surface friction as well as feedback to the student to indicate when the combination of speed and steering input is such to overcome the coefficient of friction	√			• The road situation provides cues of surface friction as well as feedback to the student to indicate when the combination of speed and steering input is such to overcome the coefficient of friction; example reviewed was a snow covered road
Off Road Recovery	Does the simulator duplicate variation in surface from road to shoulder (refer Unit 3.2 Exercise 3)?	√			• The simulator replicates the variation of surface from road to shoulder in the visual scene as well as an increase in steering effort and a "pull" of the steering in the proper direction
Rollover	The simulator shall be capable of simulating the dynamic conditions of a rollover; negotiation of a curve at excessive speed with top heavy vehicle, trailer begins to roll before tractor		√		• Visuals will not enable a complete roll-over • Dynamic movement of cab does not permit the duplication of a rollover; some cab roll is noted when negotiating a curve; simulator motion stops when "truck" inside wheels leaves ground

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Motion Fidelity	The simulator must be capable of replicating:				
	Vibration – through displays, controls, seat, seat restraint system	√			• Good feedback through motion base and steering wheel • Simulator lacks engine vibration while vehicle is stationary such as at traffic controls
	Lateral acceleration of vehicle through maneuvers such as turning	√			• Good replication of vehicle lateral dynamics such as during turns
	Longitudinal acceleration through such maneuvers as acceleration and braking	√			• Good feedback during acceleration and braking • Although adequate, cab pitch during acceleration exaggerated
	Turbulence caused by wind gust and buffet	√			• Good replication of buffeting by cross winds • Less noticeable effect during headwinds – only noticeable when wind removed
Field of View	The simulator shall provide a field of view that includes:				
	Horizontal view fromthe cab	√			• Good replication of horizontal view – extends beyond 180 degrees
	Vertical view from the cab	√			• Good replication of vertical view, full view out windscreen provided
	Left view from the cab	√			• Although adequate, driver can see top of projection screens
	Right view from the cab	√			• Good replication of right view from cab
	Mirrors	√			• Excellent mirror system. Real convex and flat mirrors utilized
Visual-Scene Fidelity	The texturing and shading of the simulator's visual scene shall be sufficient to duplicate:				
	Roadways	√			• Although adequate, roadway centerline appears wide far from vehicle – narrows to "normal" width as vehicle approaches
	Traffic Environments	√			• Although adequate, other vehicles in scene appear "squared-off"
	Buildings	√			• Buildings are well replicated
	Pedestrians	√			• Pedestrians are simple figures without fluid motion • Simulator stops when pedestrian hit

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Special Zones (construction, fire house)	√			• One "Special Zone" is available; short (~100 foot) construction road site, which is very simplistic in configuration
Sound	Engine sound replicated as a function of gear noise	√			• Although adequate, engine sound artificial. • Good replication of gear grind during gear change
	Engine sound replicated as a function of engine rpm	√			• Engine sound changes as a function of RPM
	Is cab noise present, from brakes, air, other?	√			• Although adequate, sound level high per customer specification
	Is outside noise present?	√			• Outside noise from passing vehicles present
	Is background noise present?	√			• Background noise adequate
	Is road noise present?		√		• Road noise not sufficiently distinguished from other simulated noises
	Is noise from defects such as tire failure present?	√			• Good replication of defects such as tire blow-out
	Is air buzzer present during engine start?	√			• Air buzzer is present during engine start
	General comments	√			• General good replication of system noise; noise level high per customer request; very good replication of gear grind during shifting, and noise of vehicles passing
Ambient Lighting Conditions: How does the simulator replicate?	Day	√			• Simulator replicates daytime lighting well
	Night	√			• Simulator replicates night time lighting well
	Dawn	√			• Simulator replicates dawn lighting well
	Dusk	√			• Simulator replicates dusk lighting well
	Glare			√	
Driving Stresses Fidelity	Are the following traffic densities available?				
	High Density		√		• High density traffic inadequate; although a total of 46 vehicles available in scenarios, traffic density not high enough • Instructor can not program the actions of all vehicles
	Low Density	√			• Low density traffic adequate • Instructor can not program the actions of all vehicles

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Task Fidelity	Actual tasks performed to operational criteria, for examp le, ability to use rear view mirrors in the docking maneuver of a loading bay	√			• Although the lack of depth perception of the projected image hinders backing, the mirrors can be used to adequately perform a docking maneuver • The design of the mirror system requires the driver to lean forward in order to change viewing perspective as in a real vehicle
Wind: Are the following wind effects available?	Speed effect on vehicle	√			• Speed effect on vehicle with steady wind not noticeable until wind is removed – vehicle will then accelerate
	Directional effect on vehicle	√			• Directional effect of wind on vehicle well replicated
	Gusts effect on vehicle stability	√			• Effects of gusts well replicated
	Directional effect on vehicle stability	√			• Directional effect of wind gust well replicated
Desert	Are desert conditions simulated?			√	
Adverse Weather: Are the following weather conditions provided?	Rain		√		• Rain may be replicated in simulator, but visual effect not adequate
	Snow	√			• Snow visual appearance and effect on the vehicle handling adequately replicated in simulator
	Slush			√	
	Ice	√			• Visual appearance and effect on vehicle handling on ice replicated in simulator
Poor Visibility: Are the following causes of poor visibility available on simulator?	Caused by Snow	√			• Poor visibility caused by snow adequately replicated
	Caused by Sleet			√	
	Caused by Ice			√	
	Caused by Fog	√			• Poor visibility caused by fog adequately replicated
	Caused by Mist	√			• Poor visibility caused by mist adequately replicated
	Caused by Rain	√			• Poor visibility caused by rain adequately replicated
	Caused by Dust			√	
	Caused by Smoke			√	
Freeway-to-Freeway Connectors	Does the simulator provide a geometrically constrained section of roadway, such as a freeway-to-freeway connectors, or clover-leaf	√			• Freeway to freeway connectors adequately replicated

Criterion	Factor	Available	Not Available	Explanation of Rating/Comments
Tractor Trailer Configurations	Single Trailer	√		• Single Trailer configurations of 53 foot tested and adequate • Manufacturer indicates 48 foot conventional and flat bed configurations available
	Double Trailer	√		• Double and Double Flatbed Trailer configurations available
	Triple Trailer		√	
	Tanker Trailer		√	

Special Rigs – Unit 1.9

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Double/Triple Trailers Dynamics	Simulator should duplicate the following characteristics of double and triple trailers:				
	Handling and stability	√			• Double Trailer handling and stability replication adequate
	Response to steering	√			• Double Trailer response to steering replication adequate
	Sensory feedback	√			• Double Trailer sensory feedback replication adequate
	Braking	√			• Double Trailer braking replication adequate
	Oscillatory sway	√			• Double Trailer oscillatory sway replication adequate
	Rollover in steady turns	√			• Double Trailer rollover in steady turns replication adequate
	Yaw stability in steady turns	√			• Double Trailer yaw stability in steady turns replication adequate
	Slow speeds on steep grades	√			• Double Trailer slow speeds on steady grade replication adequate
	Longer passing times	√			• Double Trailer longer passing times replication adequate
	Splash and spray impacts			√	
	Aerodynamic buffeting	√			• Double Trailer aerodynamic buffeting replication adequate
	View blockages	√			• Double Trailer view blockage replication adequate
	Lateral placement	√			• Double Trailer lateral placement replication adequate

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Tanker Vehicle Dynamics	Simulator shall replicate the following characteristics of Tanker Trailers:				
	Effects of cargo surge on vehicle handling			√	
	Proper braking when motor vehicle is empty, full or partially full			√	
	Handling baffled/compartmental tank interiors versus non-baffled motor vehicles			√	
	Differences in cargo surge for liquids of varying product densities			√	
	Effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks			√	

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructional Features	Features to facilitate training, testing of the student driver	√			• Simulator uses training tools to provide documentation in driver training, and testing, in such areas as shifting, lane keeping, emergency maneuvers
Operator's Manual	Is an Operator's manual available for use by the instructor	√			• Instructor training material available, no on-line capability
Automated Performance Measurement	Automatic calculation of time, number of trials, and errors made by each student	√			• Features available to track student performance in areas such as shifting, lane keeping, emergency maneuvers
Scenario Control	Automatically configure and control the simulator upon instructor selection of conditions – including ability to stop, start, and reposition simulator	√			• Scenario authoring on-the-fly by the instructor not available • Simulator uses previously developed driving scenarios (city, highway, mountain) that may be modified by the instructor in advance of the driving session • Although adequate, cannot control actions of all other vehicles in scenario
Initial Condition Control	Instructor control over:				
	Vehicle configuration	√			• Instructor can select vehicle configuration, such as 48 or 53 foot conventional trailer, 48 foot flatbed, double, double flatbed • Only 53 foot trailer assessed
	Roadway characteristics	√			• Full control of roadway characteristics
	Environmental conditions	√			• Full control of environmental conditions
	Vehicle handling characteristics	√			• Full control of vehicle handling characteristics
Real-time Simulation Variable Control	The simulator must be capable of controlling the insertion, removal, and alteration of simulation variables while the simulator is running a scenario	√			• The simulator allows the insertion, removal, and alteration of a number of variables while the simulator is running a scenario, such as changing the weather conditions or lighting conditions
Malfunction Control	Provide the instructor with the capability to preprogram a sequence of abnormal vehicle equipment conditions and/or emergency conditions before or during the training	√			• Instructor cannot program tire blow out on the fly • Malfunction must be pre-programmed to occur at a point in the scenario

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Reposition	Capability to position the simulator at any point in the training scenario	√			• Can reposition simulator at any point within the scenario
Instructor Overview	Provide the instructor with a meaningful depiction of the student performance during active training	√			• Simulator provides the instructor with a summary print-out of student performance during training
Bird's Eye View	Enable instructor to see vehicle interactions from above	√			• The simulator enables the instructor to see vehicle interactions from bird's eye view
Freeze	Simulator provides the capability to change certain scenario characteristics while others remain constant	√			• Simulator parameters (vehicle weight, configuration, load distribution) can be frozen at any given time within a training session
Record/Play /Demonstrate	Capability to record and reproduce all events, which occur as a consequence of student input to simulator's controls or instructor's demonstration	√			• The simulator is capable of replaying all the events which occur as a consequence of student input to simulator controls
Data Storage	Store test data by subject/test number	√			• "Instructor Management" tool provides instructor with an "electronic scorecard" to track each student's performance during the training program, prescribe remediation, and track driver performance history
Data Printout	Does simulator provide printout of driver rating, errors, performance?	√			• Data printout is available for performance items such as time behind wheel, average speed, fuel usage, transmission shifting, lane keeping, emergency maneuvers
Simulator Records	Does simulator record driver reaction times, braking distances, other factors?			√	• Driver reaction times or braking distances not available • Other performance measures, such as improper shifting, speeding are available as previously indicated

Lockheed Martin Information Systems
Millennium Driver Trainer Simulator

Simulator Specifications / Cost Information as Provided by Manufacturer

Lockheed Martin Information Systems
Millennium Driver Trainer Simulator

Criterion	Factor	Value / Comment
Sight	Minimum number of seconds road scene is ahead of the truck, distance to the sides	1000 to 3000 feet
Color	Number of colors used in visual scene (e.g., 256, infinite)	256 colors
Refresh Rate	Number of times per second visual image is refreshed	60 Hz
Field of View	Simulator Field of View	210 degrees x 40 degrees + 30 degrees mirrors
Object Visual Fidelity	Scan lines and minutes of visual arc per object	1024 x 768
Object Behavioral Fidelity	Individual objects behave autonomously and can merge, pass, speed, tailgate	Individual objects can behave autonomously and can merge, pass, speed, tailgate
Objects	Number of objects that can be simulated simultaneously in the visual scene	20
Lighting Fidelity	Luminance, spectral match	No information provided by manufacturer
Road Fidelity	Highway	Available
	Arterials	Available
	Collectors	Available
	On and off ramps	Available
	Intersections	Available
	Loop	Available
	Traffic Signals	Available
Scene Location	Urban	Available
	Rural	Available
Rail Crossings	Stop when carrying specified hazardous materials	Available
Engine	Types of engine simulated	350 HP and 500 HP engines simulated
Transmission	Types of transmissions simulated	Eaton Super 10, Straight 10, Straight 8 and 9 simulated/available
Trailer Body	Van and enclosed body	Van body, flatbed, doubles simulated
Axles	2- and 3-axle	Both 2 and 3-axle configuration available

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Criterion	Factor	VALUE / COMMENT
Acquisition Cost Information	Acquisition costs (as of 5/2001)	$750K - $800K
	Operating costs (as of 5/2001)	Information proprietary to Lockheed Martin Corporation
	Maintenance costs (as of 5/2001)	Information proprietary to Lockheed Martin Corporation
Leasing Cost Information	Leasing costs (as of 5/2001)	Information proprietary to Lockheed Martin Corporation
	Operating costs (as of 5/2001)	Information proprietary to Lockheed Martin Corporation
	Maintenance costs (as of 5/2001)	Information proprietary to Lockheed Martin Corporation
Simulator Sickness	Percent of students who experience simulator sickness	No information provided by manufacturer
User Acceptance	Feedback of simulator users on: ease of use	No information provided by manufacturer
	Cost	No information provided by manufacturer
	Sickness	No information provided by manufacturer
System Upgrades	Type of upgrades to the simulator	Following upgrades planned: -GUI-based instructor displays -Intelligent traffic capability -Enhanced topographic map features -Enhanced generic database -Sound generation Input/Output (I/O) systems -Image generator
	Schedule of upgrades to the simulator	No information provided by manufacturer
Reliability	Mean time between failures	MTBF of 300 hours expected based on similar simulators
	Number of hours of down time for maintenance	No information provided by manufacturer
Tech Support	Availability	Available in various levels of support - Lockheed Martin proprietary
	Cost	Information proprietary to Lockheed Martin Corporation
Warranties	Coverage	Available in various levels of support - Lockheed Martin proprietary
	Duration	Information proprietary to Lockheed Martin Corporation
	Cost	Information proprietary to Lockheed Martin Corporation

FAAC Incorporated
Driver Training System (DTS) Simulator

Simulator Description

5.5 Simulator System: FAAC Driver Training System (DTS) Simulator

Company: FAAC Incorporated
1229 Oak Valley Drive
Ann Arbor, MI 48108
Contact: Mr. Richard Snyder

Date of Site Visit: April 23, 2000

Introduction

This document describes a visit by the simulator evaluation Expert Team to the North American Van Lines facilities in St. Louis, MO to evaluate the Driver Training System Simulator. This location was recommended by FAAC personnel as being representative of the Driver Training System model. The meeting was hosted by the North American Van Lines personnel. As coordinated with FAAC, no representatives from the manufacturer were present during the evaluation and questions regarding the simulator were answered by North American personnel, who have been using the simulator for training truck drivers for a number of years. Subsequent questions regarding system specifications were answered by FAAC personnel.

The simulator system described in this section is available commercially from FAAC Incorporated. Acquisition and leasing costs for this system are proprietary to FAAC Incorporated.

General System Description

The following general system description was developed from informational material supplied by FAAC Incorporated and additional information gathered by the Expert Team during the aforementioned visit. This information is used with the manufacturer's permission. The DTS simulates multiple tractor-trailer configurations and offers wrap around, real-time, and realistic photo-textured graphics. The system tested did not have a motion base system. This simulator is available from the manufacturer with a motion base system. The simulator is housed in a trailer which enables the system to be transportable. The simulator consists of the following components:

Simulator Cab: The simulator cab is a partial cab system, with only the driver's seat and the dash panel ahead of the driver being duplicated. The cab is modeled after a generic truck configuration. The cab features working controls such as steering, brakes, throttle and gauges for fuel level, air pressure, oil temperature, and other parameters. The gauges are controlled by the simulator system computer while the system is in operation and provides feedback to the driver. The cab provides a 180 degree view of the driving environment out the windshield, right and left windows. The rear-view mirrors are computer generated and are within the visual scene. The simulator cab instrument panel is illustrated in Figure 14. Figure 15 illustrates the placement of the computer generated rear-view mirrors within the visual scene.

Courtesy of FAAC Incorporated

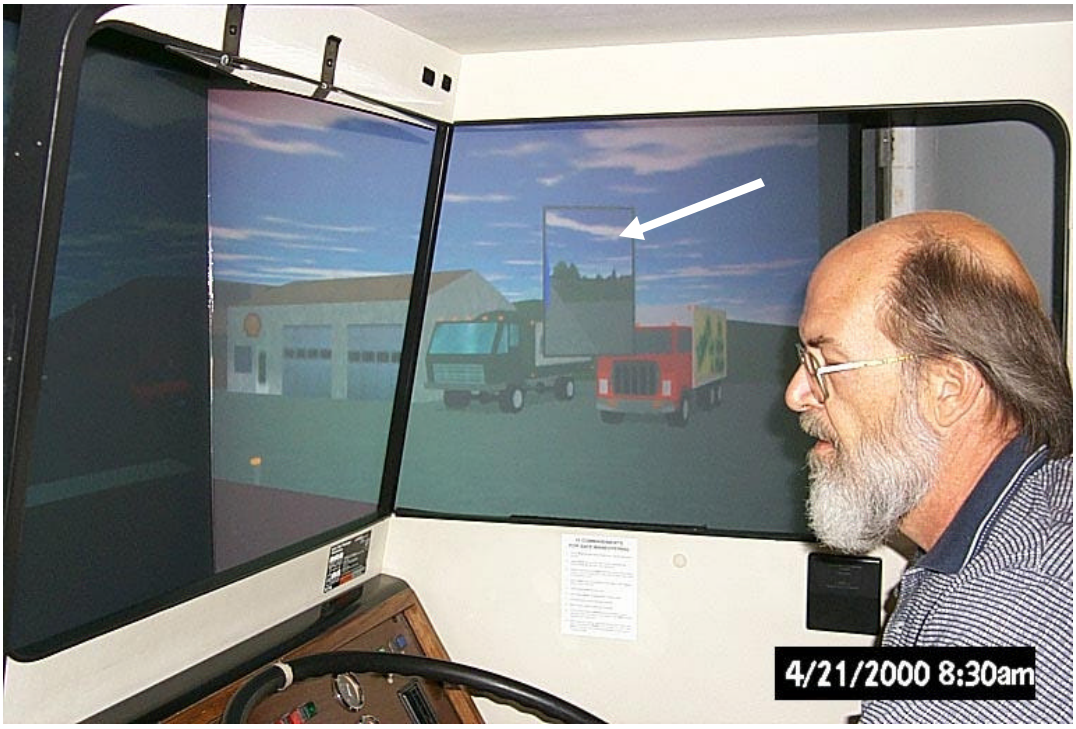
Figure 14
Simulator Control Panel

Instructor Station: The Instructor Station is used to set up simulation exercises and record trainee performance reports. It consists of a control monitor, keyboard, and mouse for exercise start-up; and a laser printer for generation of performance reports. The Instructor Station is illustrated in Figure 16. A secondary control is located on the simulated cab. This control allows the instructor to cue a malfunction, or the movement of a vehicle, such as changing lanes.

Visual System: The simulation features high resolution, computer-generated textured graphics on a wrap around screen.

Sound System: The simulator's sound system provides realistic engine, braking, and gearing sounds typical in an operating environment, as well as a variety of sounds from both inside and outside the cab.

Simulation Computer: An Intel Pentium-based computer serves as a link between the host computer and the hardware that constitutes the physical system. It executes control software that sends commands to different subsystems such as audio and instrumentation. It incorporates a high-speed data acquisition system that sends electronic control signals to, and receives the same from, the different peripheral hardware devices.



Courtesy of FAAC Incorporated

Figure 15
Cab Illustrating Mirrors in Visual Scene (note arrow showing side mirror simulation)

Courtesy of FAAC Incorporated

Figure 16
Instructor Station

Image Generator: The simulation uses a Lockheed Martin image generator that is capable of generating high resolution, photo-textured, anti-aliased, color graphics. It is also able to create effects of fog to simulate hazardous operating conditions as well as other functions like collision detection, height above terrain, visibility, environmental effects, and level of detail. The complexity of the visual scene determines the configuration of the image generator. The architecture of the image generator used is scalable according to varying customer requirements. The output of the image generator is fed to CRT projectors that in turn display the scene on high gain screens.

The DTS Simulator is housed within a 48 foot long, 8.5 foot wide, 8.8 foot tall trailer, enabling transport of the system to various training sites. This was the configuration evaluated at North American Facilities in St. Louis. The trailer is fully insulated, and is equipped with the heating and air conditioning to maintain proper temperature and humidity levels. It is self contained and requires only an external power source. The trailer is equipped with an air ride to reduce equipment wear and tear. A photograph of the trailer is presented in Figure 17.

Courtesy of FAAC Incorporated

Figure 17
Trailer Housing Simulator System

System Assessment Summary

The Driver Training System exhibited excellent graphics, good replication of control feel, especially the weighting of steering during turns, and brake feel. The system had excellent capabilities to enable a student to be trained in over-the-road skills such as speed management and gap management. The system software provided sufficient simulated vehicle traffic with programmable behavioral characteristics to allow drivers to react to situations such as vehicles cutting into the travel lane.

The simulator provided good, but limited, feedback on off-road situations such as road shoulders. A vehicle pulling off the roadway would have the transition between road and shoulder simulated by feedback from the visual scene (view of vehicle leaving road, "bump" in visual scene), and steering wheel (increased steering effort, pulling to side). However, the FAAC Driver Training System provided insufficient depth of visual field to permit the driver to

perform close quarter backing maneuvers. For example, the driver had difficulty determining the distance between the trailer and the loading dock. This lack of depth perception is a common problem in systems that rely on image generation techniques.

The FAAC Driver Training System has an excellent set of driver evaluation tools to help train drivers. Screens are available for:

- Simulation Conditions
- Test Records
- Simulation Execution
- Driver Scoring/Summary

An example of the Driver Scoring Summary screen is shown in Figure 18.

Courtesy of FAAC Incorporated

Figure 18
Driver Scoring Summary Screen

The Expert Team's detailed simulator evaluation results for the FAAC Incorporated Driver Training System are contained in the following section.

FAAC Incorporated
Driver Training System (DTS) Simulator

Expert Team Detailed Simulator Evaluation Results

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Simulator Vehicle Cab Environment	Cockpit Controls Tachometer – Does tachometer respond to throttle application, engine sound and gear that transmission is in?	√			• Tachometer adequately responds to throttle application, engine sound, and gear in which transmission is in
	Cockpit Controls Speedometer – Does speedometer respond to visual scene, motion, engine sound?	√			• Speedometer reads too fast at low speeds
	Cockpit Controls Turn Signals – Are turn signals at proper location and function?	√			• Turn signals are functional
	Other Vehicle Controls - gauges Functional or mock-up. Differential lock control, oil pressure, pyrometer	√			• Generic set of gauges in simulated cab
	Horn			√	• Horn not installed on system, available upon request
	CB Radio			√	• CB radio available upon request
	Radio			√	• Radio available upon request
	Emergency Flashers	√			• Flashers are functional
	Seat Restraint Fidelity – Does cab include three point harness?	√			• Adequate, although cab includes lap belt only, not a three-point harness
	Headlights	√			• Headlights are functional in visual scene – cone of light projected into scene
Visual Scene	View out of window Are scenery elements such as buildings, hills, etc. replicated?	√			• Although adequate, “waves” appear on horizon due to digitization of image • Representation of trees very good • Representation of buildings looks good
	View out the window Is roadway replicated correctly?	√			• Roadway replicated very well, markings and lane widths look correct
	View out of window Are roadside objects such as speed limit signs, stop signs, other signs properly replicated?	√			• Graphics on roadside objects look good

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Cab Mirrors	Left side of cab Is rear of trailer visible in mirror?	√			• Rear of trailer is visible in mirrors, running lights on trailer vis ible • Will lose sight of back end of trailer during maneuvers, exactly as in real life
	Is rear view of road visible in mirror?	√			• Visual cues provided by mirrors very good – following vehicle appearance especially good • Depth perception a problem when performing backing maneuvers – perpendicular lines placed on roadway to assist in depth perception in backing
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible
	Right side of cab Is rear of trailer visible in mirror?	√			• Rear of trailer is visible in mirrors, running lights on trailer visible • Will lose sight of back end of trailer during maneuvers, exactly as in real life
	Is rear view of road visible in mirror?	√			• Depth perception a problem when performing backing maneuvers – perpendicular lines placed on roadway to assist in depth perception in backing
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible
Road Feel	Simulator at zero indicated road speed – can engine vibration be felt?	√			• Engine vibration present in steering wheel – good representation of engine feel
	Simulator at indicated speed – can road vibration and engine vibration be felt?	√			• Although adequate, in one scenario the effects of hitting a pothole were present, (jarring of visual scene) but no pothole was seen
	Contact with curbs during turns	√			• Contact with curbs replicated by jarring of visual scene
Basic Vehicle Functionality	Vehicle responds to inputs to vehicle primary controls (steering, brakes, throttle)	√			• Steering wheel well weighted to duplicate road feel – very realistic • Braking very good without motion base – modulation of brakes possible • Throttle forces driver to be in correct gear – otherwise stall will result
	Overhead clearance			√	• Overhead clearance situations not available

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Master Basic Controls (Research Design Report Unit 1.4 NOTE: No exercise 1 in this unit)	Maneuvering in restricted quarters: Refer to Unit 1.4 "Master Basic Control" of Research Design Report for description of maneuvers				
	Exercise 2 (Serpentine)	√			• Audio notification provided every time driver runs over cone
	Exercise 3 (Figure 8)			√	• Figure 8 exercise not available with cones
	Exercise 4 (Restricted Figure 8)			√	• Restricted Figure 8 exercise not available with cones
	Exercise 5 (Turns)	√			• Turns adequate
	Exercise 6 (Restricted Turns)	√			• Restricted turns adequate
	Exercise 7 (Sharp Turns)	√			• Sharp turns adequate
	Exercise 8 (Combination Turns)	√			• Combination turns adequate
	Movable Traffic Cones	√			• Although adequate, (as shown above) cones have some restrictions on configuration
	Variable Distance Setting	√			• Distance setting of cones = trailer length + 10 feet
Turning	Is road view replicated by simulator during vehicle turning maneuvers?	√			• Representation of banked turns very good – driver can observe marker lights on trailer and marker posts on tractor
	Are the vehicle dynamics of turning replicated by simulator?		√		• Vehicle reacts quickly, dynamics replicated with visuals and sound only, no motion in cab • Although no motion base is in the tested system, motion base is available as an option through manufacturer
Transmission Shifting (Unit 1.5)	Can simulator duplicate shifting of vehicle transmission by:				
	Movement of gauge readings	√			• Driver can adequately determine when to shift transmission by use of tachometer readings
	Shifter dynamic movement	√			• Excellent shifter dynamic movement
	Can simulator provide practice in proper shifting practices?	√			• Although adequate, no grinding feel in shifter for driver feedback – grinding duplicated by audio only

FAAC Incorporated
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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Backing (Unit 1.6, example 1-3	Does the simulator duplicate the view out of the vehicle while transmission is in reverse and the vehicle is backing up?		√		• Cone size appears larger than appropriate • Lack of depth perception makes back of trailer difficult to locate with respect to buildings, loading docks
	Does the simulator duplicate the dynamics of vehicle while backing?	√			• Dynamics of the vehicle while backing replicated adequately
	Is an overhead clearance situation possible?			√	• Overhead clearance situation not available
	Exercise 1 (Alley Dock)		√		• Field of view insufficient for this maneuver – unable to see out of window to locate alley, bad for novice drivers
	Exercise 2 (Jackknife Park)		√		• Can not look out window • Convex mirror not available
	Exercise 3 (Parallel Park)		√		• Lack of depth perception makes back of trailer difficult to locate with respect to buildings, loading docks • Practice course is good – depth perception problem persists
Coupling and Uncoupling (Unit 1.7)	Can the simulator be aligned and backed up adequately to engage trailer kingpin?			√	
Cones/Pylons	Are cones or pylons available for close quarter maneuvering?	√			• Although adequate, cones are not accurately represented (too large) • Due to lack of depth perception, it is difficult to determine when vehicle is past cones on straight line/curve backing • Although adequate, (as shown above) cones have some restrictions on configuration
Uphill and	Simulator duplicates the vehicle dynamics on:				

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Downhill Terrain	Uphill road grades	√			• Difference in vehicle feedback on 20, 60, and 80 positive grades noted – excellent feature • Release of brake on positive grade caused vehicle to roll backward – good replication of actual dynamics • Simulation very responsive to steering • Hazard lights functional
	Downhill road grades	√			• Interaction of visual scene and dynamics very well represented
	Mountain Driving	√			• Mountain driving portion of scenario allow drivers good practice in "working through" the gear box
Proficiency Development: Can the simulator be set-up to perform listed maneuvers?	Close Quarter Maneuvers				
	Straight Line Backing	√			• Straight line backing dynamically good, however, lack of depth perception, and restricted view out of window makes backing up to dock difficult
	Offset Alley		√		• Lack of depth perception, and restricted view out of window makes backing up to dock difficult
	Alley Dock		√		• Depth perception is not adequate – could not determine where end of trailer is with respect to dock; yellow markings are placed on the ground to assist depth perception; this is not a real world cue
	Alley Dock – Jackknifed		√		• Lack of depth perception, and restricted view out of window makes backing-up to dock difficult
	Serpentine Forward and Reverse		√		• Forward serpentine accomplished • Could not perform reverse serpentine
	Parallel Park – Jackknifed	√			• Although adequate, lack of depth perception, and restricted view out of window makes backing up to dock difficult
	Overhead Clearance			√	

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Gap Management	The simulator must be capable of simulating the length and low acceleration of CMV's to allow the students the ability to judge adequacy of gaps for passing, entering traffic and changing lanes				
	Crossing traffic	√			• Good representation of crossing traffic
	Passing traffic	√			• Good representation of passing traffic
	Changing lanes	√			• Excellent replication of simulated vehicles changing lanes • Pre-programmed vehicles would randomly signal, or not signal, prior to lane change
	Vehicle length simulation		√		• Marker lights on trailer helped, but difficult to determine where end of trailer was during backing maneuvers
	Vehicle acceleration	√			• Vehicle acceleration adequate
	General Comments				• Good representation of traffic. Observed programmed traffic moving in and out of lane • Traffic can be observed forward and to the rear of vehicle
Speed Management	The simulator must be capable of creating conditions requiring the driver to appropriately operate vehicle transmission, brakes and throttle in the following scenarios:				
	Hills	√			• Although adequate, could not sufficiently accelerate vehicle up a hill to maintain designated speed
	Curves		√		• No sense of sway (roll) of cab in turns – an exception is a banked turn – there was a visual cue only - this was due to lack of a motion base • Inadequate ability to look down the road to determine curve radius. Could not determine sharpness of curve prior to curve entry

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Slight Upgrades	√			• Although adequate, could not sufficiently accelerate vehicle on slight upgrade to maintain designated speed
	Braking with surface texture including gravel	√			• Braking with surface texture adequate
	Parking	√			• Driver can adequately maneuver "truck" into parking area
	Turning	√			• Driver can adequately perform turning maneuvers
	Passing	√			• Programmed vehicles changed lanes too quickly
	Merging with traffic	√			• Merging with traffic adequate
	Exiting from traffic	√			• Off ramps appear too short
	Lane Change	√			• Driver can adequately perform a lane change maneuver on urban or interstate settings
Following Distance	The simulator must be capable of presenting the image of a lead vehicle in a way that accurately represents headway	√			• Simulator is very good in presenting the image of a lead vehicle in a way that accurately represents headway
Night Operation	The simulator must allow the student to be able to judge speed (relative), distance, and separation under nighttime conditions	√			• Although adequate, no high beam headlights on simulator
Emergency Maneuvering (Refer to Unit 2.6)	The simulator must be capable of creating a stimulus requiring emergency braking as well as a path along which the braking must take place; e.g., vehicle pulling in path ahead, with vehicles on left and sidewalk on the right				
	Blind intersection	√			• Blind intersection is combined with approaching traffic • Excellent simulation of blind intersection situation • Four blind intersections available
	Slippery surfaces		√		• No visual cues • Insufficient dynamic cues
	Surface resistance	√			• Effect of proceeding onto gravel surface good • Effect of proceeding onto snow surface good
	Black Ice		√		• No change in vehicle path due to black ice

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Blow-out		√		• Audio cue of blow-out present, pull on steering wheel present • No change in vehicle position, direction
	Payload overloading		√		• Although able to overload vehicle – no difference noted in vehicle feel
	Payload poor distribution		√		• Although able to change load position – no difference noted in vehicle feel
	Lack of clearance			√	
	Loose trailer brakes			√	
	Engine stalling	√			• Engine auditory cues correct
	Steering deterioration			√	
	Insecure coupling			√	
	Lane encroachment	√			• Can be set by instructor to be random or controlled
Emergency Steering (Refer to Unit 3.2)	Simulator must be able to create the sudden appearance of a stimulus in the student's path that is too close to permit the rig to be brought to a stop, but with the available lanes to permit a collision to be avoided through an evasive maneuver	√			• Simulator is able to create the sudden appearance of a stimulus in the student's path on the instructor's command; e.g., simulated vehicle passing, changing lanes, and stopping in the travel lane of the simulated tractor-trailer being driven
Brake Failure (Refer to Unit 3.2)	The simulator must be capable of defining a roadway environment in which the student must operate when the brake have failed				
	Catastrophic		√		
	Progressive		√		• No visual cue (smoke) indicative of progressive brake failure
	General Comments				• Air brakes only duplicated – no hydraulic brakes

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Skid Recovery/ Control (Refer to Unit 2.6)	The road/traffic display must provide cues of surface friction as well as feedback to the student to indicate when the combination of speed and steering input is such to overcome the coefficient of friction	√			• Although adequate, front axle lock-up/skid encountered with during the skid recovery/control maneuver
Off Road Recovery	Does the simulator duplicate variation in surface from road to shoulder (refer Unit 3.2 Exercise 3)?	√			• Simulator does provide a change in steering weighting when driver proceeds off-road – duplicating different surfaces – but no dynamic cues, such as vibration, present
Rollover	The simulator shall be capable of simulating the dynamic conditions of a rollover; negotiation of a curve at excessive speed with top heavy vehicle, trailer begins to roll before tractor		√		• Lack of physical motion in cab hindered good replication of rollover • Cab, trailer movement simulated by visuals only • Auditory warnings of tires squealing • Some feedback through steering

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Driver Training System Simulator

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Motion Fidelity	The simulator must be capable of replicating:				
	Vibration – through displays, controls, seat, seat restraint system			√	• System tested did not have a motion base, available as an option
	Lateral acceleration of vehicle through maneuvers such as turning			√	• Visual cues during turning good – no motion available in tested system
	Longitudinal acceleration through such maneuvers as acceleration and braking			√	• No pitching of vehicle cab due to lack of motion base
	Turbulence caused by wind gust and buffet			√	
Field of View	The simulator shall provide a field of view that includes:				
	Horizontal view from the cab	√			• Horizontal view from the cab adequate
	Vertical view from the cab		√		• Image projection screens are mounted too low for full visual coverage
	Left view from the cab		√		• Image does not extend far enough back for maneuvers, especially backing
	Right view from the cab		√		• Image does not extend far enough back for maneuvers, especially backing
	Mirrors	√			• Mirrors are present and functional • Although adequate: – Mirrors too far forward – Mirrors too far away – Mirrors too small – No convex mirror available
Visual-Scene Fidelity	The texturing and shading of the simulator's visual scene shall be sufficient to duplicate:				
	Roadways	√			• Could observe overpass in rearview mirrors • Signs out of focus until vehicle close to sign
	Traffic environments	√			• Although adequate, no parked cars available
	Buildings	√			• Replication of buildings good

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Pedestrians	√			• Only 2 pedestrians available • No control over placement of pedestrians
	Special zones (construction, fire house)			√	
Sound	Engine sound replicated as a function of gear noise	√			• Engine sound as a function of gear noise adequate
	Engine sound replicated as a function of engine rpm	√			• Engine sound as a function of engine rpm adequate
	Is cab noise present, from brakes, air, other?			√	
	Is outside noise present?			√	
	Is background noise present?			√	
	Is road noise present?			√	
	Is noise from defects such as tire failure present?			√	
	Is air buzzer present during engine start?			√	
Ambient Lighting Conditions: How does the simulator replicate:	Day	√			• Daytime lighting conditions adequate
	Night	√			• Night time lighting conditions very good
	Dawn	√			• Very little difference from day
	Dusk	√			• Very little difference from day
	Glare			√	• Glare lighting condition not available
Driving Stresses Fidelity	Are the following traffic densities available:				
	High Density	√			• Traffic density so high that driver can get blocked while trying to merge into traffic • Maximum of three programmable simulated vehicles can be presented (two ahead and one aside the simulated truck)
	Low Density	√			• Non-programmable vehicles move independently
Task Fidelity	Actual tasks performed to operational criteria, for example, ability to use rear view mirrors in the docking maneuver of a loading bay		√		• Lack of depth perception to rear makes task fidelity not adequate
Wind: are the	Speed effect on vehicle		√		• No sense of wind effect while driving on road

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
following wind effects available:	Directional effect on vehicle		√		• No sense of wind effect while driving on road
	Gusts effect on vehicle stability		√		• No sense of wind effect while driving on road
	Directional effect on vehicle stability		√		• No sense of wind effect while driving on road
Desert	Are desert conditions simulated?			√	
Adverse weather: Are the following weather conditions provided?	Rain			√	
	Snow	√			• Tracking effect in snow well replicated in steering feel and vehicle movement
	Slush	√			• Tracking effect in slush well replicated in steering feel and vehicle movement
	Ice		√		• No apparent effect of ice
Poor visibility: Are the following causes of poor visibility available on simulator?	Caused by snow		√		• No falling snow – just snow on ground
	Caused by sleet			√	
	Caused by ice			√	
	Caused by fog	√			• Good replication of fog
	Caused by mist	√			• Mist replication same as fog
	Caused by rain			√	
	Caused by dust	√			• Dust replicated same as fog
	Caused by smoke	√			• Smoke replicated same as fog
Freeway-to-Freeway Connectors	Does the simulator provide a geometrically constrained section of roadway, such as a freeway-to-freeway connectors, or clover-leaf	√			• Freeway-to-freeway cross ramp with stop signs are available • No clover leaf roadway configuration available

Criterion	Factor	Available	Not Available	Explanation of Rating/Comments
Tractor Trailer Configurations	Single Trailer	√		• Trailer configurations of 40, 45, and 48 foot available
	Double Trailer		√	
	Triple Trailer		√	
	Tanker Trailer		√	

Special Rigs – Unit 1.9

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Double/Triple Trailers Dynamics	Simulator should duplicate the following characteristics of double and triple trailers:				
	Handling and stability			√	
	Response to steering			√	
	Sensory feedback			√	
	Braking			√	
	Oscillatory sway			√	
	Rollover in steady turns			√	
	Yaw stability in steady turns			√	
	Slow speeds on steep grades			√	
	Longer passing times			√	
	Splash and spray impacts			√	
	Aerodynamic buffeting			√	
	View blockages			√	
	Lateral placement			√	

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Tanker Vehicle Dynamics	Simulator shall replicate the following characteristics of Tanker Trailers:				
	Effects of cargo surge on vehicle handling			√	
	Proper braking when motor vehicle is empty, full or partially full			√	
	Handling baffled/compartmental tank interiors versus non-baffled motor vehicles			√	
	Differences in cargo surge for liquids of varying product densities			√	
	Effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks			√	

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructional Features	Features to facilitate training, testing of the student driver	√			• Overhead view available from cab for replays
Operator's Manual	Is an Operator's Manual for use by the Instructor provided by the simulator?	√			• Online training manuals not available however, hard copy is available
Automated Performance Measurement	Automatic calculation of time, number of trials, and errors made by each student	√			• Very good training features available, such as driver scoring, replay of errors, rating of shifting activity
Scenario Control	Automatically configure and control the simulator upon instructor selection of conditions – including ability to stop, start, and reposition simulator	√			• Although adequate, scenario control has some limitations, such as no immediate blow-out available
Initial Condition Control	Instructor control over:	√			
	Vehicle configuration	√			• Initial condition control of vehicle configuration adequate
	Roadway characteristics	√			• Initial condition control of roadway characteristics adequate
	Environmental conditions	√			• Initial condition control of environmental conditions adequate
	Vehicle handling characteristics such as payload weight, distribution	√			• Initial condition control of vehicle handling characteristics adequate
Real-time Simulation Variable Control	The simulator must be capable of controlling the insertion, removal, and alteration of simulation variables while the simulator is running a scenario	√			• Although adequate, real time simulation variable control has some limitations, for example, system payload distribution cannot be changed on-the-fly
Malfunction Control	Provide the instructor with the capability to preprogram a sequence of abnormal vehicle equipment conditions and/or emergency conditions before or during the training	√			• Although adequate, malfunction control has some limitations however, such as a tire blow-out available only on highway scenario
Reposition	Capability to position the simulator at any point in the training scenario	√			• Ten preset reposition points available – four are independently positioned
Instructor Overview	Provide the instructor with a meaningful depiction of the student performance during active training	√			• The simulator can provide the instructor with a meaningful depiction of student performance

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Bird's Eye View	Enable instructor to see vehicle interactions from above	√			• Bird's eye view available only in cab. Student must share screen with instructor during replay. • Scenario can be picked up where stopped to restart training
Freeze	Simulator provides the capability to change certain scenario characteristics while others remain constant	√			• Freeze can be accomplished at either computer station or control panel at side of cab
Record/Play/ Demonstrate	Capability to record and reproduce all events, which occur as a consequence of student input to simulator's controls or instructor's demonstration	√			• Last ten seconds from stop of scenario is available. • Scenario can then be repositioned at any location
Data Storage	Store test data by subject/test number	√			• Data storage adequate
Data Printout	Does simulator provide printout of driver rating, errors, performance?	√			• Data printout adequate, examples include driver errors, lane position, lane changes and gear shifting
Simulator Records	Does simulator record driver reaction times, braking distances, other factors?			√	• No reaction time or braking distances are available

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Driver Training System Simulator

Simulator Specifications / Cost Information as Provided by Manufacturer

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Driver Training System Simulator

Criterion	Factor	Value / Comment
Sight	Minimum number of seconds road scene is ahead of the truck, distance to the sides	Draw range of visual scene is in excess of 2500 meters in all directions from simulator driver
Color	Number of colors used in visual scene (e.g., 256, infinite)	Infinite color capability
Refresh Rate	Number of times per second visual image is refreshed	Update rate is available at both 30 Hz and 60 Hz; 30 Hz is generally selected when increased polygon count is desired for maximum scene realism and density of static and dynamic objects; for higher driving speeds with high yaw rate capability, 60 Hz is recommended
Field of View	Simulator Field of View	FOV, in both horizontal and vertical, depends on the application of the customer. FAAC builds part-task simulators such as desk-top with limited FOV when linear driving is acceptable. When driving in traffic where complete situational awareness is critical, 360 degree coverage is provided. Vertical FOV can vary between 20 and 45 degrees depending upon application and size of window and windshield openings
Object Visual Fidelity	Scan lines and minutes of visual arc per object	Discovery of an 8 foot x 8 foot moving vehicle at ½ mile is achieved (VGA 640 x 480). Thus, for objects in the forward view, resolution is no greater than 7 arc minutes per pixel (VGA 640 x 480) and for the rear view, no greater than 10 arc minutes

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Criterion	Factor	Value / Comment
Object Behavioral Fidelity	Individual objects behave autonomously and can merge, pass, speed, tailgate	Traffic behavior is governed by artificial rule sets that make vehicles appear as if they were executing their own driving decisions. The instructor or examiner can take over control of these vehicles causing them to misbehave in common ways that we see every day. The following are driving situations for which all autonomous vehicles have specific rules governing their behavior: 1. Observance of speed limits 2. Yield for stop signs, traffic lights, yield signs, right of way 3. Merge at entrance ramps and after passing 4. Following distance 5. Passing on 2-lane roads and expressways 6. Right turn on red 7. Turn decisions at intersections/merges 8. Reaction to emergency lights and sirens During set-up, the instructor has the option to cause some or all of the vehicles to "misbehave." For example, if "misbehave" is selected, these vehicles will have an increased tendency to cut off other traffic when passing, or they may occasionally run a red light. The misbehavior by the vehicles will happen on a random basis (from the driver's point of view). A further instructor control over traffic is the ability to cause certain specific events to occur on demand. These optional scenario events include: 1. Having oncoming traffic wander across the center line into your lane 2. Having a vehicle in front of the simulator driver stop in the road for no apparent reason 3. Create a situation at a freeway entrance ramp involving merging traffic from the right as well as another moving vehicle in the lane to the left of the simulator driver 4. Having a vehicle evade an emergency vehicle Selection and command of these controlled events is available from the instructor remote keypad or directly from the IOS
Objects	Number of objects that can be simulated simultaneously in the visual scene	Up to 100 objects can be simulated simultaneously in the visual scene. This includes trucks, buses, cars, vans, motorcycles and pedestrians. Density of the traffic is set at the start of the exercise and can be changed on-the-fly during the exercise.

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Criterion	Factor	Value / Comment
Lighting Fidelity	Luminance, spectral match	No information provided by manufacturer
Road Fidelity	Highway	Available
	Arterials	Available
	Collectors	Available
	On and off ramps	Available
	Intersections	Available
	Loop	Available
	Traffic Signals	Available
Scene Location	Urban	Available
	Rural	Available
Rail Crossings	Stop when carrying specified hazardous materials	Available
Engine	Types of engine simulated	No information provided by manufacturer
Transmission	Types of transmissions simulated	No information provided by manufacturer
Trailer Body	Van and enclosed body	Enclosed van
Axles	2- and 3-axle	Three axle configuration demonstrated

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Driver Training System Simulator

Criterion	Factor	Value / Comment
Acquisition Cost Information	Acquisition costs	No information provided by manufacturer
	Operating costs	No information provided by manufacturer
	Maintenance costs	No information provided by manufacturer
Leasing Cost Information	Leasing costs	No information provided by manufacturer
	Operating costs	No information provided by manufacturer
	Maintenance costs	No information provided by manufacturer
Simulator Sickness	Percent of students who experience simulator sickness	No information provided by manufacturer
User Acceptance	Feedback of simulator users on: ease of use	No information provided by manufacturer
	Cost	No information provided by manufacturer
	Sickness	No information provided by manufacturer
System Upgrades	Type of upgrades to the simulator	No information provided by manufacturer
	Schedule of upgrades to the simulator	No information provided by manufacturer
Dependability	Mean time between failures	No information provided by manufacturer
	Number of hours of down time for maintenance	No information provided by manufacturer
Tech Support	Availability	No information provided by manufacturer
	Cost	No information provided by manufacturer
Warranties	Coverage	No information provided by manufacturer
	Duration	No information provided by manufacturer
	Cost	No information provided by manufacturer

Thales Training and Simulation
Trust 800 Simulator

Simulator Description

5.6 Simulator System: Thales Trust 800 Simulator

Company:

Thales Training and Simulation
1, Rue du General de Gaulle
Osny, BP 226
95523 Cergy-Pontoise Cede
France
Contact: Mr. Alain Flipo

Thales Training and Simulation
5233-A South 122nd East Avenue
Tulsa, OK 74146-6001
(US Address)

Date of Site Visit: May 10, 2001

Introduction

This section describes a visit by the Expert Team to the Carnegie Mellon Driver Training and Safety Institute (DTSI) in Connellsville, PA to evaluate the Thales Training and Simulation Truck Simulator for Training (Thales Trust) 800 Simulator. Thales was formerly known as Thomson Training and Simulation. A representative from Thales was present during the evaluation and assisted in answering questions and demonstrating the simulator. This location was recommended by Thales as being representative of the Trust 800 model. The meeting was hosted by the DTSI. A description of the Trust 800 simulator is provided, along with a copy of the evaluation form completed by the Expert Team. The evaluation forms presented later in this chapter present the consensus of the simulator Expert Team.

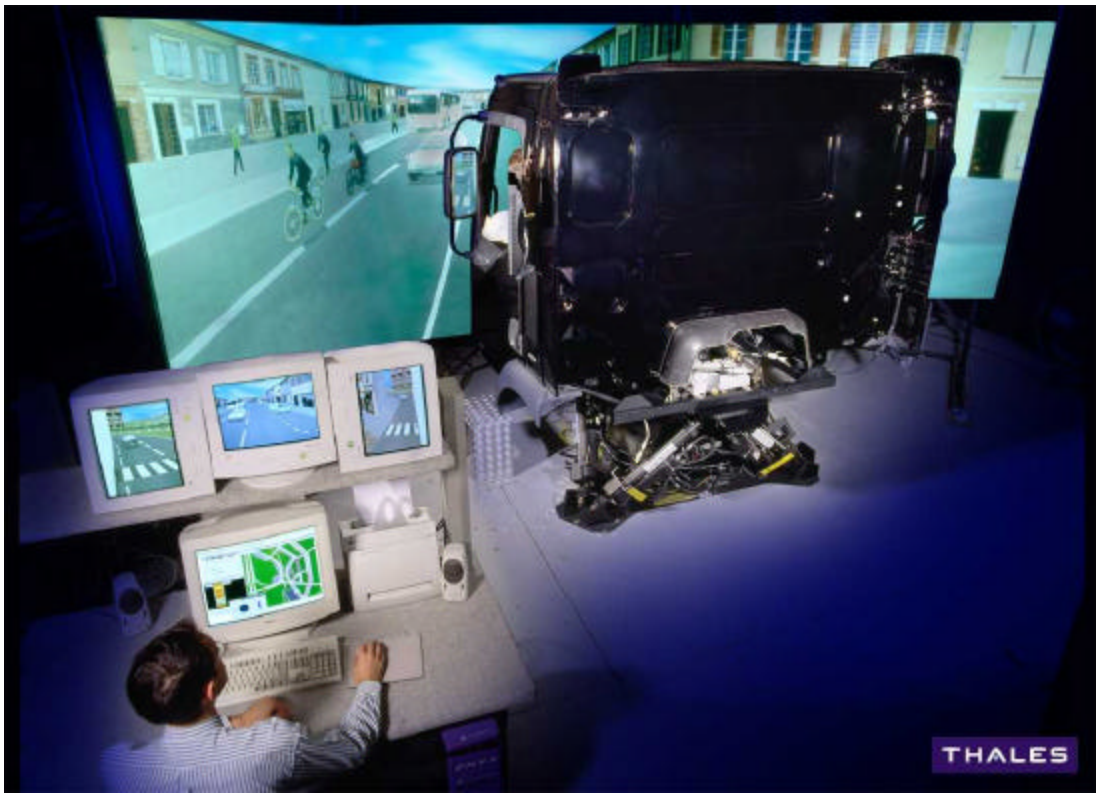
The simulator system described in this section is available commercially from Thales Training and Simulation. Acquisition and leasing cost information for this system is proprietary to Thales.

General System Description

The following general system description was developed from informational material supplied by Thales and additional information gathered by the Expert Team during the aforementioned visit. This information is used with the manufacturer's permission. Additional information was obtained during the visit by the Expert Team and is also reflected in this section. The Thales Trust 800 Simulator simulates multiple tractor-trailer configurations and offers wrap around, real-time, photo-textured graphics, and realistic cab motion. The simulator installation is depicted in Figure 19. The simulator consists of the following components:

Simulator Cab: The simulator cab is modified from a Renault 120 Premium truck available exclusively in Europe. The simulated vehicle employs a cab-over design. The simulator is programmed to duplicate the characteristics of a conventional tractor trailer. The cab features working controls and instruments. An Eaton Fuller short-throw 10-speed gearshift is provided. The cab offers a full view of the driving environment with a windshield, right and left windows, and rearview mirrors on the right and left of the cab. A view of the cab instrument panel is provided in Figure 20.

Motion System: Hydraulic actuators beneath the cab provide the motion cues. The hydraulic



Courtesy Thales Training and Simulation

Figure 19
Thales Simulator Installation

motion system provides vibrations present under normal driving conditions, jolts during rough road driving, and motion caused by braking, accelerating, turning, and skidding. A photograph of the Thales motion system is provided in Figure 21.

Visual System: The simulation features high resolution, computer-generated textured graphics on a wrap around screen. Adjustable rearview mirrors with correct perspective are also included.

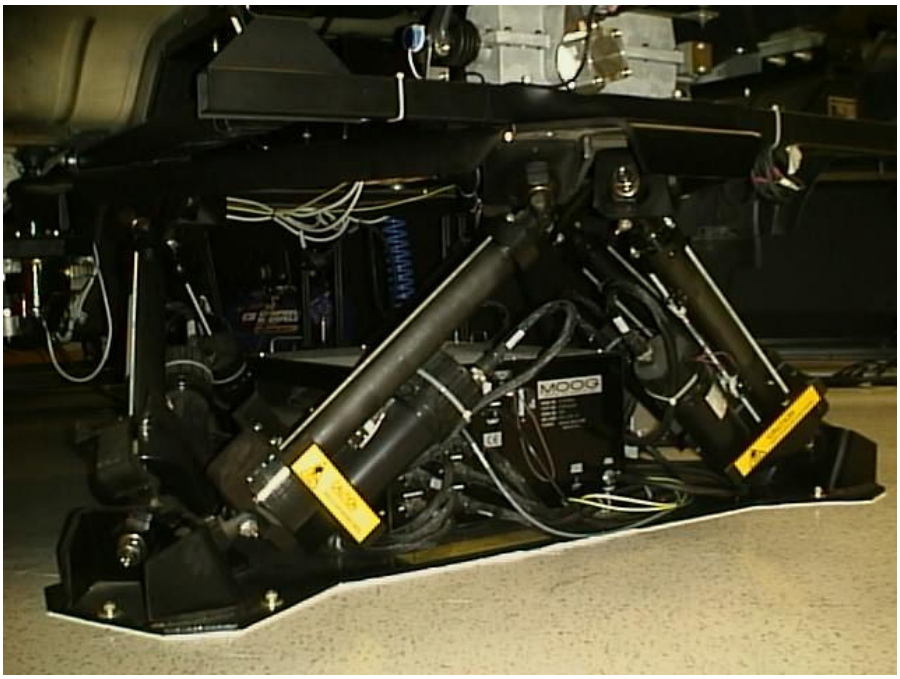
Instructor Station: The Instructor's Station is used to set up simulation exercises and record trainee performance reports. It consists of a control monitor, keyboard, and mouse for exercise start-up. Three color monitors are provided to allow the instructor a view of what the trainee sees during the simulation session. The system also includes a laser printer for generation of driver performance reports. The Instructor Station may be observed on the left portion of Figure 22.

The simulator can operate in one of three modes: Presentation, Training, and Evaluation. Each of these modes is described below:

- Presentation Mode:
  In this mode vocal messages can be sent from the instructor station to the cab to convey information or knowledge.

Courtesy Thales Training and Simulation

Figure 20
Trust 800 Cab Instrument Panel



Courtesy Thales Training and Simulation

Figure 21
Trust 800 Motion System

- Training Mode:
  In the Training Mode of Operation drivers may practice various maneuvers. A driver performance evaluation can be checked on screen and printed, but not recorded for long term use. Failure in a specific maneuver however does not preclude the trainee from advancing to another exercise.

- Evaluation Mode:
  In this mode the trainee is evaluated and recorded. The student can practice the same exercise, but with less guidance messages. The trainee's evaluation is recorded for skill acceptance and long term records.

Each training exercise can be played in any of the above modes, according to the instructor's choice. The training exercises are created on the Exercise Creation Tool, entitled CREX. This authoring tool provides a means for the user to create a wide variety of simulator exercises in an assortment of scenarios and environments. This tool permits the definition of specific task conditions, setting of computerized evaluation parameters, and creation of exercises that can be performed in the self instruction Training Mode.

Sound System: The simulator's sound system provides realistic engine, braking, and gearing sounds typical in an operating environment, as well as a variety of sounds from both inside and outside the cab.

System Assessment Summary:

The Thales Trust 800 utilizes a modified cab system of a Renault 120 Premium cab-over truck sold exclusively in Europe. The cab-over was modified to provide the visual graphics of a conventional tractor-trailer configuration as seen from the driver's perspective. Additional modifications include installation of a hand air brake control on the dash, and installation of an Eaton Fuller short-throw 10-speed gearshift lever. Most conventional tractors have 10-speed transmissions, with long throw shifters. The simulator vehicle dynamics software was modified to represent a conventional tractor-trailer configuration. The simulator vehicle model provides three trailer configurations, 53-foot and 48-foot conventional trailer and a tanker trailer. The Expert Team assessed the 53-foot and tanker trailer configurations only. The cab presents a basic set of gauges to the driver, including speedometer, tachometer, oil pressure, water temperature, voltage, fuel pressure and air tank pressure. The speedometer uses kilometer per hour (KPH) as the primary measure on the outer arc, with miles per hour (mph) on the inner arc. This is the reverse of the conventional systems used in the United States. The cab includes a mirror system on the right and left sides of the cab. The mirrors are real mirrors that observe a scene generated by a LCD monitor mounted at the back of the cab assembly. The mirror assembly is illustrated in Figure 22.

Courtesy Thales Training and Simulation

Figure 22
Thales Rear View Mirror and LCD Screen

The throttle response of the simulated engine was slow, even for a tractor-trailer, and was deemed "not adequate." Visual cues outside the cab and motion cues correlate with slow acceleration. Also, the brakes did not respond well to modulation, instead they were either full on or off. The motion cues, pitch, roll, and vibration of the simulated vehicle are good at low speeds (less than 35 mph), while less accurate at higher speeds.

The Thales simulator features a driving range that permits students to practice basic vehicle control techniques such as serpentine, backing, and jackknife backing. This was a useful feature, permitting a structured environment to perform these maneuvers. The Thales simulator provides training in mountainous terrains. The scenarios combine a good variety of curves and uphill/downhill sections. Instructional features for the simulator are highly customized for the simulator customer. The simulator lacks the capacity to observe the trainee in the cab, although there is communication via a two-way microphone system. The scenarios lack sufficient traffic to replicate dense traffic environments, although the traffic density is sufficient for low density traffic scenarios. In addition, available traffic cannot be programmed to cluster around the simulated vehicle. The simulator has extensive features for providing driver performance evaluation and feedback. The data from a training session can be recorded while the simulator is in Evaluation mode of operation.

The Expert Team's detailed simulator evaluation results for the Thales Trust 800 system are contained in the following section.

Thales Training and Simulation
Trust 800 Simulator

Detailed Expert Team Simulator Evaluation Results

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Simulator Vehicle Cab Environment	Cockpit Controls Tachometer – Does tachometer respond to throttle application, engine sound and gear that transmission is in?	√			• Although adequate, there is a delayed response of tachometer gauge to throttle input
	Cockpit Controls Speedometer – Does speedometer respond to visual scene, motion, engine sound?	√			• Although adequate, the speedometer has kilometers per hour (KPH) as the primary units, and miles per hour (MPH) as the secondary, contrary to practice in the United States
	Cockpit Controls Turn Signals – Are turn signals at proper location and function?		√		• Turn signals use European paradigm, e.g., when turn signal stalk is activated, both directional lights in cab flash
	Other Vehicle Controls - gauges Functional or mock-up. Differential lock control, oil pressure, pyrometer	√			• Additional gauges include oil pressure, water temperature, voltage, fuel pressure, air tank pressure
	Horn	√			• The horn is a simplistic, computer generated representation
	CB Radio			√	
	Radio			√	
	Emergency Flashers	√			• Emergency flashers are present and have realistic look in the cab when engaged
	Seat Restraint Fidelity – Does cab include three point harness?	√			• Full three-point harness available for driver and passenger
	Headlights		√		• Lights appear to project from above the hood. Hood appears lighted by vehicle's headlights as if lights are mounted on top of the vehicle cab

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	General Comments				• Cab is a converted Renault 120 cab-over design • Two-way microphone used for communication between driver and instructor • No capacity for the instructor to observe the trainee in the cab while instructor is at the Instructor Station – for example, no camera to watch driver eye scan
Visual Scene	View out of window Are scenery elements such as buildings, hills, etc. replicated?	√			• Buildings are simplistic • Hills, trees, other scenery present in visual scene
	View out the window Is roadway replicated correctly?	√			• Road is well replicated • Center and roadway edge lines well replicated • Road and shoulder width appear too narrow directly in front of vehicle in all scenarios
	View out of window Are roadside objects such as speed limit signs, stop signs, other signs properly replicated?	√			• Speed limit signs are in MPH – primary speedometer scale in KPH • Stop signs, traffic signals well replicated in most scenarios
Cab Mirrors	Left side of cab Is rear of trailer visible in mirror?		√		• Trailer tires not visible in mirrors, as they would be in a real truck; this makes back of trailer difficult to locate in backing and other maneuvers
	Is rear view of road visible in mirror?	√			• Rear view of road is visible in mirror
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible in mirror
	Right side of cab Is rear of trailer visible in mirror?		√		• Trailer tires not visible in mirrors, as they would be in a real truck as noted above
	Is rear view of road visible in mirror?	√			• Rear view of road is visible in mirror
	Is rear view of road edge visible in mirror?	√			• Rear view of road edge is visible in mirror
Road Feel	Simulator at zero indicated road speed – can engine vibration be felt?			√	• No engine vibration present when vehicle stationary

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Simulator at indicated speed – can road vibration and engine vibration be felt?	√			• Road vibration is present when vehicle is in motion • Engine vibration is present when vehicle is in motion
	Contact with curbs during turns	√			• Good replication of curb contact in cab motion cues and visual scene
Basic Vehicle Functionality	Vehicle responds to inputs to vehicle primary controls (steering, brakes, throttle)		√		• Lag in response of throttle • Steering feels too light for a tractor trailer when speeds are greater than 35 mph • Brake input produced very delayed reduction of speed
	Overhead clearance	√			• Overhead clearance situation present in tunnel scenario
Master Basic Controls (Research Design Report Unit 1.4 NOTE: No exercise 1 in this unit)	Maneuvering in restricted quarters: Refer to Unit 1.4 "Master Basic Control" of Research Design Report for description of maneuvers				
	Exercise 2 (Serpentine)	√			• Simulator can replicate Exercise 2
	Exercise 3 (Figure 8)	√			• Simulator can replicate Exercise 3
	Exercise 4 (Restricted Figure 8)	√			• Simulator can replicate Exercise 4
	Exercise 5 (Turns)	√			• Simulator can replicate Exercise 5
	Exercise 6 (Restricted Turns)	√			• Post distances in exercise lengthened to accommodate 53 foot trailers
	Exercise 7 (Sharp Turns)	√			• Post distances in exercise lengthened to accommodate 53 foot trailers
	Exercise 8 (Combination Turns)	√			• Simulator can replicate Exercise 8
	Movable Traffic Cones	√			• Posts can be repositioned
	Variable Distance Setting	√			• Post distances can be modified in each scenario, but not by instructor on-the-fly, e.g., during an exercise while the simulator is being driven, the post positions must be preprogrammed

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	General Comments				• Only 53-foot trailer evaluated for basic control maneuvers • Scenario development features: – Posts used instead of cones for set-up of maneuvers – Exercises set-up for 48-foot trailer. Post spacing expanded to accommodate 53-foot trailer – Excellent features
Turning	Is road view replicated by simulator during vehicle turning maneuvers?	√			• Road edge markings and center line markings replicated well at low speeds. • Road view at speeds greater than 35 MPH not replicated as well
	Are the vehicle dynamics of turning replicated by simulator?	√			• At speeds below 35 MPH, replication of turning dynamics (cab roll, steering feel) acceptable • At speeds above 35 MPH dynamics should be more apparent, although adequate
Transmission Shifting (Unit 1.5)	Can simulator duplicate shifting of vehicle transmission by:				
	Movement of gauge readings	√			• Although adequate, there was a delayed response of tachometer gauge readings following throttle input
	Shifter dynamic movement		√		• Simulator employs a short throw shifter typical of a cab-over design, as opposed to shifter typical in conventional tractor trailers • Transmission shifting requires excessive effort
	Can simulator provide practice in proper shifting practices?	√			• Simulator has an exercise that can be used when the simulator is not in motion, making system a part-task transmission trainer • As discussed previously the simulator is difficult to shift
Backing (Unit 1.6, example 1-3	Does the simulator duplicate the view out of the vehicle while transmission is in reverse and the vehicle is backing up?	√			• Simulator adequately replicates the view out of the vehicle while transmission is in reverse and vehicle is backing up

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Does the simulator duplicate the dynamics of vehicle while backing?	√			• Simulator adequately replicates the dynamics of the vehicle while backing
	Is an overhead clearance situation possible?	√			• Overhead clearance available in multiple driving scenarios
	Exercise 1 (Alley Dock)	√			• Alley dock can be accomplished on driving range setting
	Exercise 2 (Jackknife Park)	√			• Jackknife Park can be accomplished on driving range setting
	Exercise 3 (Parallel Park)	√			• Parallel Park can be accomplished on driving range setting
Coupling and Uncoupling (Unit 1.7)	Can the simulator be aligned and backed up adequately to engage trailer kingpin?			√	
Cones/Pylons	Are cones or pylons available for close quarter maneuvering?	√			• Posts are used for maneuvering training instead of cones • Striking a post causes the simulation to stop; simulator must be re-started to continue scenario

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Uphill and Downhill Terrain	Simulator duplicates the vehicle dynamics on:				
	Uphill road grades	√			• Speed decreases as vehicle proceeds along uphill grade as in a real tractor trailer
	Downhill road grades	√			• Simulator adequately replicates increase in vehicle speed while on downgrade • Simulator uses a magnetic driveline brake and an exhaust brake in lieu of a "JAKE" (engine compression) brake which are more common on U.S. long haul trucks for auxiliary braking • Transmission shifting requires excessive effort
	Mountain Driving	√			• Good mountain driving scenario available
Proficiency Development: Can simulator be set-up to perform listed maneuvers?	Close Quarter Maneuvers	√			• Simulator provides a driving range to perform close quarter maneuvers – an excellent feature
	Straight Line Backing	√			• Driving range scenario provides good straight line backing capabilities
	Offset Alley	√			• Driving range scenario provides good offset alley capabilities
	Alley Dock	√			• Driving range scenario provides good alley dock capabilities
	Alley Dock – Jackknifed	√			• Driving range scenario provides good alley dock – jackknifed capabilities
	Serpentine Forward and Reverse	√			• Driving range scenario provides good serpentine capabilities
	Parallel Park – Jackknifed	√			• Driving range scenario provides good parallel park – jackknifed capabilities
	Overhead Clearance	√			• Driving range scenario provides good overhead clearance proficiency development

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Gap Management	The simulator must be capable of simulating the length and low acceleration of CMV's to allow the students the ability to judge adequacy of gaps for passing, entering traffic, and changing lanes:				
	Crossing traffic	√			• Replication of crossing traffic adequate, although additional traffic more desirable
	Passing traffic	√			• Although adequate, high density traffic scenarios do not provide sufficient traffic
	Changing lanes	√			• Replication of changing lanes adequate
	Vehicle length simulation	√			• Replication of 53 foot trailer length adequate, 48 foot trailer not tested
	Vehicle acceleration		√		• At speeds less than 35 MPH acceleration generally adequate • Visual scenes correlate with unusually slow vehicle acceleration • At speeds greater than 35 MPH acceleration not generally replicated well • No feeling of acceleration such as vehicle pitch from dynamics model and motion base
	General Comments				• The simulator provides conditions to allow drivers to judge the adequacy of vehicle-to-vehicle headway for lane changes and passing • Vehicle response to throttle input on acceleration delayed
Speed Management	The simulator must be capable of creating conditions requiring the driver to appropriately operate vehicle transmission, brakes and throttle in the following scenarios:				
	Hills	√			• Simulator creates adequate hill scenarios

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
	Curves	√			• Simulator creates adequate curve scenarios • Vehicle responds in an appropriate manner if curve is negotiated at too high a speed, e.g., vehicle moves to outside of curve, but does not rollover as described in roll-over criterion
	Slight Upgrades	√			• Vehicle correctly responds to hill with reduction in vehicle speed
	Braking with surface texture including gravel		√		• No change in braking noticed with different surfaces, i.e., gravel and grass
	Parking	√			• Vehicle can be slowed for parking maneuvers
	Turning	√			• Vehicle speed can be modulated for turning maneuvers
	Passing	√			• Although adequate, slow throttle response hinders passing
	Merging with traffic	√			• Although adequate, slow throttle response hinders merging with traffic
	Exiting from traffic	√			• Vehicle speed can be modulated to permit exiting from traffic or onto exit ramps
	Lane Change	√			• Although adequate, slow throttle response hinders lane change
	General Comments				• Although speed management can be performed adequately in general, throttle response is delayed, braking effort cannot be modulated (brakes full on or off), and transmission shifting is cumbersome and hinders speed management
Following Distance	The simulator must be capable of presenting the image of a lead vehicle in a way that accurately represents headway	√			• Simulator adequately presents the image of a lead vehicle in a way that accurately represents headway
Night Operation	The simulator must allow the student to be able to judge speed (relative), distance, and separation under nighttime conditions		√		• Headlights not adequate for night driving. Overall light pattern, and effect of light not correctly presented as previously noted in vehicle cab criterion

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Emergency Maneuvering (Refer to Unit 2.6)	The simulator must be capable of creating a stimulus requiring emergency braking as well as a path along which the braking must take place; e.g., vehicle pulling in path ahead, with vehicles on left and sidewalk on the right				
	Blind intersection	√			• Multiple blind intersections available
	Slippery surfaces	√			• Slippery surfaces due to snow or rain are available on highway scenario
	Surface resistance	√			• Roadway surface resistance can be changed with snow or rain. No noticeable effect on grass or gravel
	Black ice			√	
	Blow-out		√		• Tire blow-out feels like a slight bump, no effect on vehicle path or steering feel • Tire blow-out, combined with failed air suspension, had a more realistic effect on steering feel and vehicle path
	Payload overloading			√	
	Payload poor distribution		√		• While able to distribute payload, no difference in vehicle handling was noticed
	Lack of clearance	√			• Lack of clearance (side, overhead) situations available with multiple scenarios
	Loose trailer brakes			√	• Loose trailer brakes not available in system
	Engine stalling	√			• Simulated vehicle engine may be stalled when driver selects inappropriate gear/RPM combination
	Steering deterioration			√	• Unable to reduce steering response
	Insecure coupling			√	• Insecure trailer coupling not available
	Lane encroachment	√			• Simulator can adequately replicate a lane encroachment situation by another vehicle or by simulated vehicle on another vehicle

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Emergency Steering (Refer to Unit 3.2)	Simulator must be able to create the sudden appearance of a stimulus in the student's path that is too close to permit the rig to be brought to a stop, but with the available lanes to permit a collision to be avoided through an evasive maneuver	√			• Two scenarios available and well replicated: - Vehicle stopped suddenly in lane - Pedestrian stops in cross walk
Brake Failure (Refer to Unit 3.2)	The simulator must be capable of defining a roadway environment in which the student must operate when the brakes have failed:				
	Catastrophic	√			• Catastrophic failure of brakes available only in mountain driving scenario • Electromagnetic emergency braking system replicated in simulator not widely used in US tractor trailers
	Progressive			√	• Progressive brake failure not available
	General Comments				• Brake response generally poor • No modulation of brakes – brakes must be pumped to bring vehicle to a gradual halt
Skid Recovery/ Control (Refer to Unit 2.6)	The road/traffic display must provide cues of surface friction as well as feedback to the student to indicate when the combination of speed and steering input is such to overcome the coefficient of friction	√			• Simulator adequately replicates skid control on highway scenario with snow covered roads
Off Road Recovery	Does the simulator duplicate variation in surface from road to shoulder (refer Unit 3.2 Exercise 3)		√		• No feel of drop off to shoulder or grass through motion base and steering • Visual cues indicate off-road condition, but cab motion lacks off-road feel
Rollover	The simulator shall be capable of simulating the dynamic conditions of a rollover; negotiation of a curve at excessive speed with top heavy vehicle, trailer begins to roll before tractor			√	

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Motion Fidelity	The simulator must be capable of replicating:				
	Vibration – through displays, controls, seat, seat restraint system	√			• Vibration is present while simulated vehicle is in motion • No vibration from engine while vehicle is stationary
	Lateral acceleration of vehicle through maneuvers such as turning	√			• Although adequate, replication of lateral acceleration is better at speeds less than 35 mph than at speeds greater than 35 mph
	Longitudinal acceleration through such maneuvers as acceleration and braking		√		• Poor acceleration and braking replication
	Turbulence caused by wind gust and buffet		√		• No difference in vehicle path noted with wind gust and buffet
Field of View	The simulator shall provide a field of view that includes:				
	Horizontal view from the cab	√			• Horizontal view from cab is adequate
	Vertical view from the cab	√			• Vertical view from cab is adequate
	Left view from the cab	√			• Left view from cab is adequate
	Right view from the cab	√			• Right view from cab is adequate
	Mirrors	√			• Although adequate, system lacks convex mirrors
Visual-Scene Fidelity	The texturing and shading of the simulator's visual scene shall be sufficient to duplicate:				
	Roadways	√			• Replication of roadways adequate
	Traffic environments	√			• Although adequate, insufficient traffic for high density traffic situations
	Buildings	√			• Although adequate, buildings are simplistic, lack detail
	Pedestrians	√			• Although adequate, pedestrians are artificial in appearance and movement
	Special zones (construction, fire house)			√	

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Sound	Engine sound replicated as a function of gear noise	√			• Gear grind replicated in cab
	Engine sound replicated as a function of engine RPM	√			• Engine sound as function of RPM adequate
	Is cab noise present, from brakes, air, other?	√			• Cab noise is present
	Is outside noise present?	√			• Wind noise noted, other vehicles in traffic
	Is background noise present?	√			• Background noise noted from road
	Is road noise present?	√			• Tire noise is present
	Is noise from defects such as tire failure present?	√			• Although adequate, tire failure sound not realistic
	Is air buzzer present during engine start?	√			• Air buzzer present
Ambient Lighting Conditions: How does the simulator replicate:	Day	√			• Adequate replication of day conditions
	Night	√			• Adequate replication of ambient night conditions
	Dawn	√			• Adequate replication of dawn conditions
	Dusk	√			• Adequate replication of dusk condition
	Glare			√	
Driving Stresses Fidelity	Are following traffic densities available:				
	High Density		√		• Insufficient number of vehicles for high density traffic
	Low Density	√			• Low density traffic environments adequate
Task Fidelity	Actual tasks performed to operational criteria, for example, ability to use rear view mirrors in the docking maneuver of a loading bay	√			• Although adequate, unable to see the trailer's rear tires in mirrors as described previously
Wind: Are the following wind effects available:	Speed effect on vehicle		√		• No effect on vehicle noted
	Directional effect on vehicle		√		• No effect on vehicle noted
	Gusts effect on vehicle stability		√		• No effect on vehicle noted
	Directional effect on vehicle stability		√		• No effect on vehicle noted

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Desert	Are desert conditions simulated?			√	
Adverse Weather: Are the following weather conditions provided?	Rain		√		• No change in vehicle handling or image of road with rain
	Snow	√			• Snow adequately replicated • Vehicle handling appropriately effected
	Slush			√	
	Ice			√	
Poor Visibility: Are the following causes of poor visibility available on simulator?	Caused by snow			√	• Poor visibility caused by falling snow not available
	Caused by sleet			√	
	Caused by ice			√	
	Caused by fog	√			• Poor visibility caused by fog adequate
	Caused by mist			√	• Poor visibility caused by mist not available
	Caused by rain		√		• Rain insufficient to cause poor visibility
	Caused by dust			√	
	Caused by smoke			√	
Freeway-to-Freeway Connectors	Does the simulator provide a geometrically constrained section of roadway, such as a freeway-to-freeway connector, or clover-leaf	√			• Freeway-to-freeway connectors are available

Criterion	Factor	Available	Not Available	Explanation of Rating/Comments
Tractor Trailer Configurations	Single Trailer	√		• Simulator adequately replicates 53 foot single trailer • 48 foot trailer available but not evaluated
	Double Trailer		√	
	Triple Trailer		√	
	Tanker Trailer	√		• Full load tanker, ½ load, and empty tanker available • General visual representation good

Special Rigs – Unit 1.9

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Double/Triple Trailers Dynamics	Simulator should duplicate the following characteristics of double and triple trailers:				
	Handling and stability			√	
	Response to steering			√	
	Sensory feedback			√	
	Braking			√	
	Oscillatory sway			√	
	Rollover in steady turns			√	
	Yaw stability in steady turns			√	
	Slow speeds on steep grades			√	
	Longer passing times			√	
	Splash and spray impacts			√	
	Aerodynamic buffeting			√	
	View blockages			√	
	Lateral placement			√	

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Tanker Vehicle Dynamics	Simulator shall replicate the following characteristics of Tanker Trailers:				
	Effects of cargo surge on vehicle handling	√			• Simulator adequately replicates effects of surge on vehicle handling with ½ loaded tanker trailer • Empty and full tanker configurations not tested
	Proper braking when tanker is empty, full or partially full		√		• No difference noted in braking with full, ½, or empty
	Handling baffled/compartmental tank interiors versus non-baffled motor vehicles			√	• Baffled/compartmentalized tank interiors not available
	Differences in cargo surge for liquids of varying product densities			√	• Differences in cargo surge of liquids of varying densities not available
	Effects of road grade and curvature on motor vehicle handling with filled, half-filled, and empty tanks		√		• No effect of road grade with full, ½, or empty condition noted in scenarios driven

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Instructional Features	Features to facilitate training, testing of the student driver	√			Although adequate, • Instructor Station is located in a separate room, therefore, the Instructor cannot observe student in cab • Communication between driver and Instructor occurs via 2-way microphone system
Operator's Manual	Is an Operator's Manual available for use by the Instructor?	√			• Hard copy documentation available for: – Self instruction station in cab – Exercise creation tool entitled "CREX" – Instructors Station operation
Automated Performance Measurement	Automatic calculation of time, number of trials, and errors made by each student	√			• Driver training data is saved in system "Evaluation" mode. This mode permits scoring of driver inputs and operation of "vehicle" as described in General System Description • "Training" and "Practice" modes allow for printing of data following each exercise. However, when a new exercise is started, data from previous exercise is no longer available unless printed • Session start/end time appears only on system screen, not print-out
Scenario Control	Automatically configure and control the simulator upon instructor selection of conditions – including ability to stop, start, and reposition simulator	√			• Most scenario authoring must be performed off-line. • Some features can be chosen or changed at Instructor Station while the system is in operation. Examples are weather and day/night lighting conditions
Initial Condition Control	Instructor control over:	√			
	Vehicle configuration	√			• Vehicle configuration must be selected by Instructor in advance of training session while simulator is off-line
	Roadway characteristics	√			• Good selection of road types, such as city, mountain, highway
	Environmental conditions	√			• Day/night, fog, rain set in exercise creation tool (CREX)
	Vehicle handling characteristics	√			• Adequate, but limited to vehicle payload weight, distribution

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Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Real-time Simulation Variable Control	The simulator must be capable of controlling the insertion, removal, and alteration of simulation variables while the simulator is running a scenario	√			• Adequate, but limited to only a few features such as vehicle load, payload distribution, and lighting conditions • Most variables can not be changed on-the-fly
Malfunction Control	Provide the instructor with the capability to preprogram a sequence of abnormal vehicle equipment conditions and/or emergency conditions before or during the training	√			• Limited to a few features: – Air brake failure – Electromagnetic brake retarder failure – Shifting of load (slosh) on tanker trailer configuration – Front tire blow-out – Air suspension failure
Reposition	Capability to position the simulator at any point in the training scenario	√			• Although adequate, this capability is cumbersome and randomly caused system computer to crash
Instructor Overview	Provide the instructor with a meaningful depiction of the student performance during active training	√			• System permits observation of driver's view of forward, left, right sides of vehicle using three separate monitors at the Instructor Station
Bird's Eye View	Enable instructor to see vehicle interactions from above	√			• Overhead view of vehicle and scene available at Instructor Station
Freeze	Simulator provides the capability to change certain scenario characteristics while others remain constant	√			• Simulator provides the capability to change certain scenario characteristics while others remain constant such as lighting conditions
Record/Play/ Demonstrate	Capability to record and reproduce all events, which occur as a consequence of student input to simulator's controls or instructor's demonstration	√			• Simulator can adequately provide a playback of the visual scenario and actions of the driver
Data Storage	Store test data by subject/test number	√			• Data storage available only in "evaluation" mode of operation or as hard copy printed information • Presentation and Training modes of operation do not permit storage of driver training data

Criterion	Factor	Adequate	Not Adequate	Not Available	Explanation of Rating/Comments
Data Printout	Does simulator provide printout of driver rating, errors, performance?	√			• Extensive driver training data printouts are available for the trainee • Data as described below can be plotted in table form or as bar charts
Simulator Records	Does simulator record driver reaction times, braking distances, other factors?	√			• System uses Accident Prevention Plus (APP) to measure and collect these data. APP is a data logging system that can be used in the simulator, or in a real truck. Parameters such as truck RPM, speed, acceleration are recorded

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Simulator Specifications / Cost Information as Provided by Manufacturer

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Criterion	Factor	Value / Comment
Sight	Minimum number of seconds road scene is ahead of the truck, distance to the sides	No data provided
Color	Number of colors used in visual scene (e.g., 256, infinite)	No data provided
Refresh Rate	Number of times per second visual image is refreshed	60 Hz
Field of View	Simulator Field of View	180 degree horizontal, 45 degree vertical
Objects	Number of objects that can be simulated simultaneously in the visual scene	30 vehicles
Object Visual Fidelity	Scan lines and minutes of visual arc per object	No data provided
Object Behavioral Fidelity	Individual objects behave autonomously and can merge, pass, speed, tailgate	Yes
Lighting Fidelity	Luminance, spectral match	1000+ Lumens
Headlights	High and low beam	Available
Road Fidelity	Highway	Available
	Arterials	Available
	Collectors	Available
	On and off ramps	Available
	Intersections	Available
	Loop	Available
	Traffic Signals	Available
Scene Location	Urban	Available
	Rural	Available
Rail Crossings	Stop when carrying specified hazardous materials	Available
Engine	Types of engine simulated	Generic Engine
Transmission	Types of transmissions simulated	Eaton-Fuller 10 speed, short throw cab-over configuration

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Criterion	Factor	Value / Comment
Trailer Body	Van and enclosed body	Enclosed single, tanker
Tractor Axles	2- and 3-axle	Two and Three axle
Acquisition Cost Information	Acquisition costs	Thales proprietary
	Operating costs	Thales proprietary
	Maintenance costs	Thales proprietary
Leasing Cost Information	Leasing costs	Thales proprietary
	Operating costs	Thales proprietary
	Maintenance costs	Thales proprietary
Simulator Sickness	Percent of students who experience simulator sickness	No data provided
User Acceptance	Feedback of simulator users on:	
	Ease of use	No data provided
	Cost	No data provided
	Sickness	No data provided
System Upgrades	Type of upgrades to the simulator	System Upgrades Performed: • Installation of a simulated Eaton Fuller short throw 10 speed gearbox • Incorporation of gear clash sound effect • Installation of conventional hand air brake control on dashboard • Installation of MPH readings on speedometer minor scale • Installation of improved intercom system to facilitate communication between instructor and student • Modification of databases to incorporate U.S. road configurations, English language signs • Creation of conventional truck configuration with 48-foot, 53-foot enclosed trailers, tanker trailer configuration
	Schedule of upgrades to the simulator	Accomplished December 2000
Reliability	Mean time between failures	No data provided

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Criterion	Factor	Value / Comment
	Number of hours of down time for maintenance	No data provided
Tech Support	Availability	Thales proprietary
	Cost	Thales proprietary
Warranties	Coverage	Thales proprietary
	Duration	Thales proprietary
	Cost	Thales proprietary

Acronyms

ABBREVIATION	DEFINITION
AASHTO	American Association of State Highway Traffic Organizations
BTW	Behind the Wheel
CB	Citizen's Band Radio
CDL	Commercial Drivers License
CMV	Commercial Motor Vehicle
CRT	Cathode Ray Tube
CMU	Carnegie Mellon University
DOF	Degree of Freedom
DTS	Driver Training System
FAA	Federal Aviation Administration
FERT	Final Exam Road Test
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
GUI	Graphical User Interface
GVWR	Gross Vehicle Weight Ratings
HP	Horse Power
HZ	Hertz
KPH	Kilometers per Hour
LCD	Liquid Crystal Display
MPH	Miles Per Hour
PSRT	Pre-Street Road Test
PTDI	Professional Truck Driver Institute
TCD	Traffic Control Device
RFP	Request for Proposal
RPM	Revolutions Per Minute
VMT	Vehicle Maneuver Trainer
VCR	Video Cassette Recorder

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